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ELECTRICITY

IN MEDICINE AND SURGERY

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A TEXT-BOOK

OF

ELECTRICITY IN MEDICINE AND SURGERY

FOR THE USE OF STUDENTS AND PRACTITIONERS

BY

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LONDON
SMITH, ELDER, & CO., 15 WATERLOO PLACE
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THE AUTHOR

PREFACE.

THIS WORK is not intended to be exhaustive, nor entirely original, but the aim of the Author has been to produce a book which shall prove of practical use to students and practitioners.

He has endeavoured to regard his subject from the point of view of a physician who has access to many therapeutic agents, and who is expected to use his judgment in the selection of a remedy for any particular case; and he has tried to avoid appearing in the character of a special pleader who is blind to all facts which tell against his client for the time being.

He has endeavoured so to fortify his readers with a knowledge of the principles which underlie the subject in hand that they may approach the treatment of a case with intelligence; and he has, he trusts, included in the text all those well-established scientific facts which are capable of a clinical application.

As a physician, the author must apologise for attempting to write on the surgical applications of Electricity, but he feels that his work would be far less useful had the surgical sections been omitted. This, therefore, is his excuse; and he must beg the indulgence of those who may discover shortcomings in Chapters VIII. and X.

Some portions of the text have appeared previously in the pages of the 'Practitioner' and the 'Lancet,' in the form of abstracts of lectures given at Charing Cross Hospital, but by far the greater part has been written expressly for this volume.

A considerable space has been devoted to the treatment of aneurism by galvano-puncture, because the Author feels that a full discussion of a mode of treatment which may be said to be still upon its trial cannot but prove interesting and useful.

Some apology is necessary for the great length at which the subject of 'fatigue diseases' is treated, but the Author was naturally anxious to state fully his views on a matter which seems to him of no small importance.

The Author has been very largely indebted to the works of others, but he has purposely omitted foot-notes and references as much as possible. The writings of Ziemssen, Duchenne, Reynolds, Mayer, Morgan, Tripier, Cyon, Althaus, Tibbitts, Benedict, Walter Smith, Lincoln, Bryant, Radcliffe, Anstie, Buzzard, Bastian, and very many others, have been freely laid under contribution.

To Messrs. Weiss, and Messrs. Mayer and Meltzer, who have kindly furnished some of the wood-cuts, the author begs to tender his best thanks.

30 Wimpole Street, W.: *January* 1876.

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ELECTRICITY

IN

MEDICINE AND SURGERY.

CHAPTER I.

PRINCIPLES.

We think it advisable, before touching on any of the various details of our subject, to endeavour to give the reader some general notion of the place which electricity should hold in the catalogue of Materia Medica. We may begin by asserting that no other single artificial therapeutic agent is so generally useful, or admits of so many and such varied applications. An electric battery in the hands of a medical man, who has mastered some of the first principles of electricity, is capable of being turned to a great variety of uses, some of which undoubtedly may be better performed by many other agents which we have at our command. For others it stands alone and supreme, and will occasionally help a patient on his road to recovery when everything else has failed to render him the slightest service. Electricity apparently has the power of evoking function in every form of living tissue, and this power entitles it to a high place amongst those remedies which we call *stimulants*. It has hitherto been chiefly employed in medicine as a stimulant to muscular tissue, and a great part of the ensuing volume will be found to be devoted to this application of electricity. It is likewise a stimulant to nervous tissue; and motor and sensory nerves, nerves of special sense, and the nerve-centres themselves, all readily respond to the electrical stimulus. Tissues which are not so intimately connected with the nerves are also influenced by electrical currents, and there is no doubt that, by their judicious application, nutritive processes may be modified, and the rate of secretion of certain glands (salivary, &c.) be quickened.

Like many other stimulant medicines, electricity has also very marked anodyne and soothing qualities, and its reputation as a remedial agent is based very largely on its great power in this direction. The chemical effects of electricity, and its power of decomposing compound fluids, have caused it to be used for dissolving tissues, and indeed its caustic action is not excelled by any of our ordinary escharotics. It has also a marked power in bringing about the coagulation of the blood, and for this end it has been used in the treatment of aneurisms. Surgeons have found in electricity a convenient and manageable source of heat, and at present the galvanic cautery takes a recognised and acknowledged place amongst surgical instruments. To those who ask, What are the uses of electricity in medicine? we may reply that, according to its method of employment, it may be a *stimulant*, *anodyne*, *sedative*, *caustic*, *styptic*, or *cautery*.

Electricity is used in medicine, not only for its therapeutic power, but also on account of its value as a means of diagnosis. By it we are often enabled to decide as to the seat or nature of a paralysing lesion; the electric probe has enabled surgeons to speak with certainty as to the presence of bullets in wounds, and it is possible that in the thermo-electric pile we may some day find a practical and accurate means of determining the temperature of the surface of the body.

Writers on Materia Medica are accustomed to deal, firstly, with the natural history of every therapeutic agent, its source of origin or its mode of manufacture; secondly, they pass to a consideration of its physiological action, and from the physiological facts they are accustomed, in the third place, to deduce certain rules for our guidance as to its therapeutic employment. We shall follow a similar course in this work; and although it is to be feared the reader will find that the basis of electro-therapeusis is empirical rather than physiological, we should not on that account be justified in disregarding the facts which have been established as to electro-physiology.

Electricity has been used in medicine in its three most usual forms. First, in the form which is generated in so-called batteries, and which has been called the *battery current*, or, in honour of its discoverer, *Galvanism*, or, in honour of its chief investigator, *Voltaic electricity*, or, by reason of its usual method of employment, the *continuous current.* Secondly, it has been employed—and largely employed—in the form of the '*induced current*;' the form which has been named, after our countryman, *Faradism*, and which, from its usual method of employment, is not uncommonly spoken of as the *interrupted current.* Thirdly, it has been employed in the form of *frictional electricity*, such as is generated by the friction of glass discs, or cylinders, and which has also received the name of *static electricity*, or, in honour of its chief original investigator, *Franklinism.*

These three forms of electricity generated from batteries, or by induction, or by friction, and which we shall speak of as Galvanism, Faradism, and Franklinism, are to be kept distinct in the mind, and—being employed, as they are, for widely different purposes—must no more be confounded together than the three narcotics, opium, chloral, and Indian hemp.

In dealing with a subject like this, nothing is so important as to begin really at the beginning; and since some knowledge of electrical principles is absolutely necessary for the proper comprehension of the subject with which we have to deal; and since, at present, electricity is not one of the subjects a knowledge of which is usually required of the legally qualified practitioner, we feel that no excuse is needed for detaining the reader a short time with the consideration of some first principles. Surely it is better to run the risk of telling him that which perhaps he may already know, than to leave him uninformed upon certain points which necessarily constitute the very foundations of our subject.

Galvanism, or the battery current, owes its origin to chemical action, which is allowed to take place in a series of cells.

The galvanic cell in its simplest form consists of two plates of different metals immersed in a fluid which is capable of acting chemically upon one of them, or which, if it exerts a chemical action upon both, affects one more powerfully than the other. When the two metals so immersed are connected together by a wire, a current of electricity passes along the wire; and if a galvanometer be interposed in the length of the conducting wire, its needle will be deflected, thus giving proof positive as to the existence of an electric current.

The simplest form of the galvanic cell consists of a plate of zinc and a plate of copper immersed in dilute sulphuric acid, and connected by means of a copper wire. Thus our conditions are fulfilled, since dilute sulphuric acid exerts a powerful chemical action upon zinc, but none, or next to none, upon the copper. The zinc plate, being the one which is chemically acted upon, is called the generating plate of the battery, while the copper is spoken of as the collecting plate of the battery. It is important to remember that the electric current takes a definite direction, and that it always travels *in the cell*, from the generating to the collecting plate, from the zinc to the copper, and, consequently, outside the cell, it continues in the same direction, in order to complete its circuit, and travels from the copper to the zinc. If the connecting wire be cut in two, that end of it which is joined to the copper plate is called the positive pole, and that end which is joined to the zinc plate is called the negative pole. It is important to remember that the current invariably travels from the positive to the negative pole, and it will be found, when we come to speak of therapeutics, that a knowledge of this fact must be constantly borne in mind.

A number of cells, such as we have described, may be united in a series, the copper of one being joined to the zinc of the next, and in this way a battery of any size may be constructed; or, in other words, a battery of any number of elements, and the strength of a battery is, *cœteris paribus*, proportional to the number of elements it contains.

It is not absolutely necessary that the various pairs of elements composing a battery, provided they be kept moistened and separated, should be immersed in separate cells. The well-known battery, called the Voltaic pile, consisted of discs of zinc and copper, separated by discs of wet cloth. The battery, known as Pulvermacher's chain, is composed of cylinders of zinc enclosed in links of copper; and when the various elements composing such a chain are moistened with an exciting fluid, such as vinegar, a current is generated having an intensity proportional to the length of the chain.

These simple arrangements are not capable of furnishing a constant supply of electricity, and batteries composed of such elements are liable to a rapid decrease of power from the moment of their being set in action. From this cause such batteries are of little use for medical purposes.

The cause of this decrease of power is evident. The dilute sulphuric acid tends to form sulphate of zinc, at the expense of the zinc plate, and thus the acid liquid becomes every moment less and less acid, and less and less capable of exerting any action upon the zinc plate.

A second and more important and powerful cause for the diminution of the current is the so-called *polarization* of the copper plate. It is well known that one of the results of the action of dilute sulphuric acid upon zinc is the generation of hydrogen, and part of the hydrogen so generated is deposited as a film upon the surface of the copper plate. This film of hydrogen offers great resistance to the passage of the current, and reducing the sulphate of zinc in solution causes a deposit of metallic zinc upon the copper plate, thus tending to destroy the current by bringing about a similarity between the two plates (the current, as we have said above, depending on the *difference* between them).

This defect has been almost entirely overcome by the invention of elements, which are capable, for a considerable length of time, of giving a constant current of electricity.

Daniell's constant element consists of two liquids and two metals. The copper is immersed in dilute sulphuric acid, which is saturated with sulphate of copper, and is separated from the simple dilute sulphuric acid, in which the zinc is immersed, by means of a vessel of porous earthenware.

The hydrogen liberated in the zinc-acid chamber traverses the wall of the porous vessel, reduces the sulphate of copper, and causes a deposit of metallic copper on the copper plate; and the sulphuric acid liberated from the copper solution passing through the porous vessel helps to keep up the strength of the acid on the other side of it. The elements known as the *Becker-Muirhead* elements, which have attained a considerable reputation in this country both for medical and telegraphic purposes, and also those known as the *Siemens-Halske* elements, which are largely used for medical purposes on the Continent, are both of them modifications of the Daniell element.

Other well-known constant elements are those of *Grove*, and the modification of them known as *Bunsen's* elements. In Grove's element we have two metals, platinum and zinc, and two fluids, strong nitric acid and dilute sulphuric acid. The platinum, immersed in strong nitric acid, is separated from the zinc and dilute sulphuric acid by means of a vessel of porous earthenware. In this element the hydrogen liberated in the zinc chamber traverses the porous vessel, and combining with some of the oxygen in the nitric acid, causes the escape of fumes of nitrous acid.

Bunsen's battery is, in principle, exactly similar to Grove's, the plate of platinum being merely superseded by a rod of compact gas-carbon (the carbon extracted from the retorts of the gas-works). This substitution of gas-carbon for platinum lessens the initial cost; but the carbon has the disadvantage of being very brittle and liable to break at slight causes.

Grove's and Bunsen's batteries are not employed for medical purposes, excepting in those cases where a powerful current is needed for a short time, as during the employment of the galvanic cautery and the galvanic ecraseur.

Modifications of Bunsen and Grove are abundantly used for medical purposes. The modified Bunsen consists of plates of gas-carbon and zinc immersed, both of them in one liquid, dilute sulphuric acid.

This form of element is employed in the medical batteries manufactured by Dr. Stöhrer, of Dresden, and by Messrs. Mayer and Meltzer, and others in this country. The carbon may be replaced by plates of silver, roughened on the surface by a deposit of finely divided platinum, which seems to prevent the adhesion of the hydrogen to the surface of the collecting plate. This is known as Smee's element, and is employed in the medical batteries manufactured by Messrs. Weiss. Another well-known modification of Bunsen's element is that employed in Stöhrer's induction apparatus. The carbon is moulded into the form of a hollow vessel, which is filled with sand moistened with chromic acid. In this element the hydrogen, passing through the porous carbon vessel, reduces the chromic acid.

An element largely employed for induction apparatus is known as Grenet's element, and consists of a zinc and a carbon plate, both immersed in the same liquid, a solution of bichromate of potash, to which a certain proportion of strong sulphuric acid has been added. In this element the hydrogen reduces the chromic acid to chromic oxide, which remains dissolved in the sulphuric acid.

Duchenne speaks very highly of the batteries which he has employed, composed of elements which we owe to the ingenuity of M. Marié-Davy. They may be called the sulphate of mercury battery and the sulphate of lead battery. In the first a rod of gas-carbon is packed in a porous cell with a paste made of sulphate of mercury. The porous cell is surrounded by a zinc cylinder which is immersed in pure water. In the sulphate of lead battery the sulphate of mercury is replaced by a paste made of sulphate of lead and a solution of sea salt. The carbon is replaced by a thin plate of copper and the pure water in the containing vessel by a solution of sea salt. The last is the cheaper element of the two, and it is stated that the current derived from it remains constant for many months.

The smallest element which has been introduced into medical practice is Gaiffe's chloride of silver element, consisting of a plate of zinc and a plate of compressed chloride of silver, separated by a pad of bibulous paper moistened with salt and water.

The element which at present deservedly holds the first place in public estimation is the *Leclanché element*, and there can be little doubt that it is destined to replace all other forms of element which have hitherto been used for medical purposes. This element is *patent*, the right of manufacture in this country being held by the India Rubber and Telegraph Company (Limited), but it can be obtained through any instrument maker. It consists of zinc and gas-carbon. The gas-carbon is packed in a porous cell with coarsely-powdered gas-carbon and native peroxide of manganese (pyrolusite). This porous cell is placed in an outer vessel, containing a rod of zinc and a saturated solution of chloride of ammonium. The chemical action which takes place is as follows :—Chloride of zinc is formed and hydrogen and ammonia are set free. The ammonia is absorbed by the water in the outer vessel, while the hydrogen, passing through the porous cell, reduces the peroxide of manganese. The Leclanché element can be obtained of any size, those for medical use being of about the capacity of two-

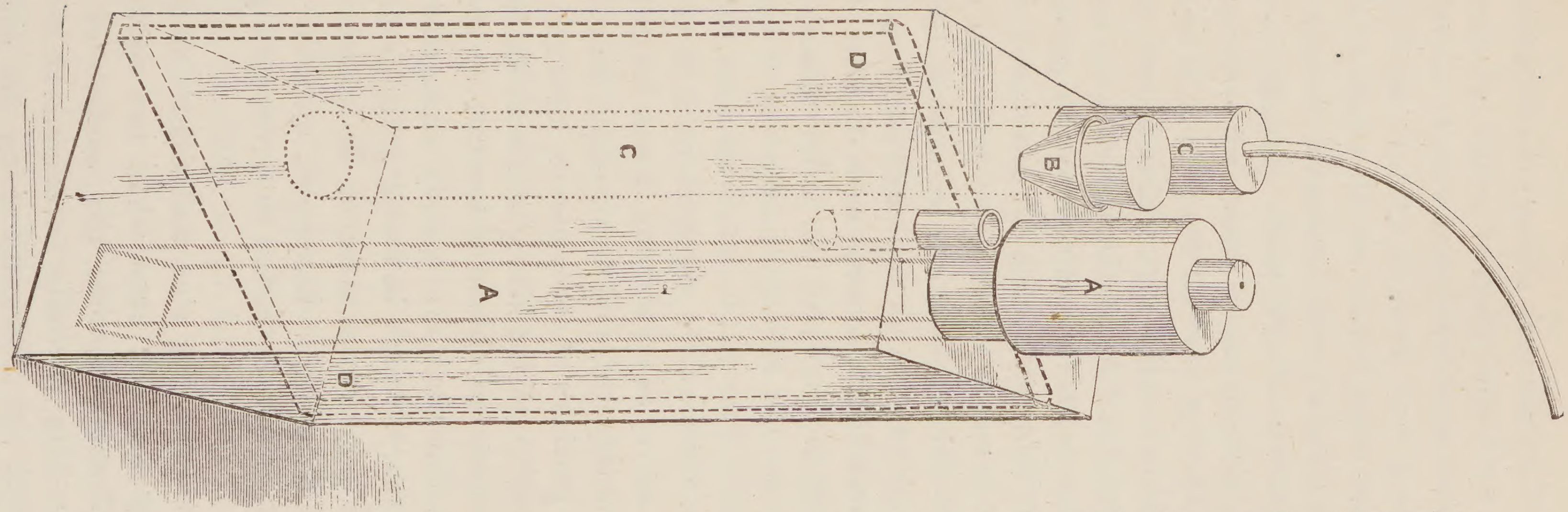

FIG. 1.—Leclanché, medical element, actual size. A—rod of gas-carbon packed in compartment DA, with pyrolusite and gas-carbon. B—funnel-shaped opening, provided with a cork, for filling compartment DC, which holds the chloride of ammonium, with water. C—rod of zinc. D—porous diaphragm, dividing the cell into equal portions. The medical Leclanché cell is usually triangular in form, and not square, as represented in the figure.

ounce bottles. They are very strong; the fluid in them cannot be spilt by any movement short of actual inversion; they are little liable to get out of order, and remain almost absolutely constant for two or more years at a time. M. Tripier says:—'For the last four years I have almost abandoned the protosulphate of mercury pile for the Leclanché element. . . . These couples, *which cause no sensible waste when the circuit is open*, work, for medical use, many years, without requiring any attention. . . . Having tried all the piles that have been proposed, I have stopped at this last, which I have employed for induction apparatus and for stationary galvanic batteries.'

The author is certainly inclined to the same opinion as M. Tripier. In February, 1874, he purchased a Leclanché element for the purposes of demonstration and experiment. After being used for the author's lectures at Charing Cross Hospital, it was put away in a cupboard and forgotten. Nine months later it was found, covered with dust and the solution of chloride of ammonium in the outer vessel, evaporated almost to dryness. On testing it, however, it was found to furnish a sufficient current to work an induction coil, and at present (July, 1875), after eighteen months of neglect, it is apparently as active as on the day it was bought.

Owing to the impurities of commercial zinc and its impregnation with particles of other metals, local galvanic action is liable to be set up at the zinc plate, causing its rapid destruction, even when the circuit of the battery is not closed. To obviate this, the zincs are usually amalgamated on the surface with mercury, which is found partially to arrest the local action. If sulphate of mercury be added to the acid liquid in which the zinc is immersed, metallic mercury is deposited upon the zinc plate, and thus the amalgamation is maintained.

All elements containing zinc and dilute acid are, however, exceedingly wasteful, even when the circuit is open. The practice of amalgamating the surface of the zincs with mercury is only partially successful in stopping the local action, which is constantly going on whenever the zincs are immersed in the acid. In consequence of this constant waste, it has been necessary to furnish all batteries having zinc and acid elements with a special mechanism for liberating the elements from the acid, whenever the battery is not required for use. In the Leclanché element, however, there is no wasteful action when the circuit is open; and it is not the least advantage of employing this element that the mechanism above-mentioned is unnecessary; and thus we gain in simplicity and save in cost, bulk and weight. On comparing a battery of sixty 'Smee' elements with a Leclanché battery of fifty elements, it appears that, while the former occupies a cubic space of 1,696 cubic inches and weighs 42 lbs., the latter occupies a space of 714 cubic inches and weighs only 25 lbs. The fact that the Leclanché element is patent has, perhaps, somewhat hindered its adoption by manufacturers of batteries; but Messrs. Weiss, whose reputation for perfection of mechanical detail and workmanship in the matter of batteries is so deservedly high, have at length united the Leclanché element to their own accessories, and the result cannot fail to be satisfactory. In using a Leclanché battery one caution is necessary, viz., never to leave the poles of the battery in *metallic* contact, *i.e.*, united by a wire. If this accident should happen the battery would 'run down' in a few hours.

These details concerning the various elements may have proved wearisome; but a knowledge of their construction is absolutely necessary. The most perfect batteries are liable to strike work at slight causes; and without some knowledge of the construction of the elements and the chemical changes which take place in the cells, the practitioner will often find himself in difficulties, and will, perhaps, be sending his battery to the manufacturers for repairs which he might effect himself in a few minutes.

When a number of elements are united together in a series to form a battery, the generating plate of one element is put in connection with the collecting plate of the next, and so on, and the first generating plate and the last collecting plate of the series are united by a good conductor. When the two terminals are united by the conductor the circuit is said to be closed, and electrical action takes place. When they are not so united the circuit is said to be open, and electrical action ceases.

We have said that the various elements and the terminals must be united by a good conductor, and this brings us to speak of *conductors* and of *non-conductors.*

There are certain bodies which electricity traverses with greater or less ease—such are the metals, charcoal, acid liquids, and the animal body—and these are called conductors. There are, again, certain bodies which electricity traverses with the greatest difficulty—such as resins, gutta-percha, baked wood, and porcelain—and these are called non-conductors or insulators, because, when a conductor, charged with electricity, is surrounded by a non-conductor, the electricity with which the conductor is charged cannot escape, or, in other words, it is insulated.

There is, however, no conductor so perfect but that it offers some resistance to the passage of the current. Conductors differ enormously—*cæteris paribus*—in the resistance which they oppose to the current. The metals are the best conductors, and the best of the metals in this respect are silver, copper, and gold. Hence it is that copper, from its cheapness and low resistance, is so largely employed in the manufacture of galvanic batteries and conductors. The resistance offered by the metals varies very much, and it has been found that the resistance offered by lead and mercury is respectively about ten times and fifty times as great as that offered by copper.

The resistance of the best conducting liquids is vastly greater than that of metals. In round numbers, the resistance of dilute sulphuric acid is a million times, and that of a solution of sulphate of copper is ten million times, greater than that of pure silver.

It is important to bear in mind that we have to do with a very bad conductor indeed—one whose resistance to the current has been spoken of as colossal—we mean the human body. In the last edition of Dr. Althaus' book will be found much interesting and instructive information on this point, but for the present we will merely content ourselves with saying that the resistance of the human body is infinitely great; and the author may add that, not long since, the resistance of his own body was found to be more than twice as great as that of the Atlantic cable. The resistances of various bodies, metals, liquids, &c., have been measured and compared to certain fixed standards, and thus, what is known as the *specific resistance* of these bodies, has been determined and may be expressed in numbers.

Metals, liquids, and animal bodies have all their specific resistances; those of the last being infinitely greater than those of the first, while liquids hold an intermediate position. With regard to liquids, we may add that the concentrated acids offer the least resistance, and distilled water the most. Dilute acids and saline solutions hold an intermediate position.

While, then, electricity is traversing conductors, it is constantly encountering and overcoming resistances more or less great. The electricity generated at the zinc plate of a Daniell's element has, in making the circuit, to overcome the resistance offered, firstly, by the dilute sulphuric acid surrounding the zinc plate, which is considerable; secondly, that offered by the solution of sulphate of copper, which is greater still; thirdly, that offered by the copper plate; and lastly, that of the copper wire, which unites the copper to the zinc plate again.

Now the resistance offered by a conductor depends not only upon the specific resistance of that conductor, but on other considerations as well. It will be obvious that a conductor a mile in length must offer a greater resistance than one a yard in length; and such is found to be the fact, the resistance offered by the one being 1,760 times that of the other. In other words, the resistance offered by a conductor is directly proportionate to its length. A long stretch of liquid, wire, or animal tissue offers a resistance in exact proportion to its length.

Again, resistance is found to be influenced by another point, and that is, the area of the cross-section of the conductor. A wire of big calibre conducts better than one of small calibre, or, in other words, the resistance offered is in an inverse proportion to the area of the cut section. Electricity may be compared to water in a pipe, which necessarily traverses a short pipe of large diameter much easier than it traverses a long pipe of small diameter. A battery constructed for the galvanic cautery, and one designed for ordinary therapeutic purposes, offer very different amounts of resistance to the current. In the one, which is probably a large Grove's battery, we find that the plates used are very large and thin, or, in other words, they have a short length and enormous transverse section. Again, we find that the plates are as closely approximated as possible, so that we have in the conducting liquids the same conditions as in the conducting plates, viz., short length and enormous transverse section. Again, the liquids employed are both good conductors, one being a dilute acid and the other a strong acid. Further, the conducting-wire is short and of large diameter. In this arrangement the resistance is everywhere at a minimum, and, consequently, the quantity of electricity evolved is enormous. In the other arrangement (a Smee, for example) we have smaller plates, more widely separated in proportion to their size; one liquid, which offers a moderate resistance; and longer conductors, which when in use include a greater or less amount of the human body.

In speaking of resistances, we have to distinguish between the resistance offered by the battery itself, which is called intra-batterial or internal resistance, and that offered by the circuit outside the battery, which is called extra-batterial or external resistance.

We must now ask the reader once more to turn his attention to the different varieties of elements which we have enumerated. These have not all the same electric power, or, as it is more properly called, the same electro-motive force. Those elements in which the greatest amount of chemical action takes place have the greatest electro-motive force—the greatest power of generating and propelling, as it were, the electricity originating in them. The electro-motive force of a Grove or Bunsen is greater than that of a Daniell or Smee. Taking the electro-motive force of a Grove as 100, that of a Bunsen is said to be 98, and that of a Daniell only 56. The electro-motive force of a Smee is, again, scarcely half that of a Daniell, while the electro-motive force of the Leclanché element is slightly in excess of the Daniell's element.

The amount of attention which a battery requires is usually in direct proportion to its electro-motive force, so that, for this reason as well as others, the practical physician uses for general purposes elements of low electro-motor power, such as Leclanché, Daniell, Smee, or Stöhrer.

That which is called the *Intensity* of an electric current depends upon the quantity of electricity which in an unit of time flows through a section of the circuit, and in all parts of the circuit the intensity is always uniform.

We are now in a position to consider Ohm's law, a right understanding of which is indispensable for the satisfactory study of electro-therapeutics. Ohm's law is to this effect, that the intensity of a current is equal to the electro-motive force divided by the resistance; or

$$I=\frac{E}{R}.$$

Now we have pointed out that the resistance offered to a current is of two kinds, intra-batterial and extra-batterial. If we designate the one by R and the other by r, then our formula becomes

$$I=\frac{E}{R+r}.$$

Supposing we multiply the number of our elements—say by 6—then the formula becomes

$$\mathrm{I}=\frac{6\,\mathrm{E}}{6\,\mathrm{R}+r};$$

for by increasing the number of elements we increase the intra-batterial resistance. The result of such multiplication of elements will be different according to the value of r—the extra-batterial resistance. Let us suppose that the value of r is practically 0, as is often the case when the circuit of a battery is completed by a metallic conductor of large calibre, then r may be neglected and our equation becomes

$$\mathrm{I}=\frac{6\,\mathrm{E}}{6\,\mathrm{R}+0}=\frac{\mathrm{E}}{\mathrm{R}}.$$

Thus the intensity of the current, in the case we have supposed, has remained the same after the multiplication of the elements. Hence arises the law that—

'*When the resistance of the circuit is insignificant in comparison with the resistance of the element, the intensity of the current is not increased by the multiplication of the elements.*'

Next, let us suppose that the intra-batterial resistance is insignificant when compared with the extra-batterial, then R becomes a quantity which we may neglect, and our equation becomes $\mathrm{I}=\frac{6\,\mathrm{E}}{0+r}=\frac{6\,\mathrm{E}}{r}$. In this case by multiplying our elements by 6 we have increased the intensity of our current 6 times, or nearly so.

Hence the next rule is—

'*When the resistance of the element is insignificant in comparison with that of the circuit, the intensity of the current increases proportionally to the number of the elements.*'

Let us now take our first supposition again—that the resistance of the circuit is insignificant when compared with that of the element—and instead of multiplying our elements by 6 let us increase their sectional area 6 times, then our equation becomes

$$\mathrm{I}=\frac{\mathrm{E}}{\frac{\mathrm{R}}{6}+0}=\frac{6\,\mathrm{E}}{\mathrm{R}}.$$

In this case we have multiplied our intensity by 6, and we get a third rule, which is—

‘When the resistance of the circuit is insignificant in comparison with the resistance of the elements, the intensity of the current increases in proportion to the surface of the elements.’

When, however, there is great extra-batterial resistance—when R is insignificant in comparison with r—we get no increase of intensity by increasing the surface.

$$\mathrm{I}=\frac{\mathrm{E}}{\frac{0}{6}+r}=\frac{\mathrm{E}}{0+r}=\frac{\mathrm{E}}{r}.$$

To sum up we may say,

‘When one has to deal with very great resistance in the circuit, the intensity of the current is increased by multiplying the number of elements, without regard to their surface, which may be as small as one likes. If, on the contrary, the resistance in the circuit is very small, then the same end is attained by increasing the surface of each element without increasing the number.’

M. Cyon, whose work ‘Principes d’Électrothérapie,’ is well worthy of perusal, thus comments on the importance of a knowledge of Ohm’s law in Electro-Therapeutics.

‘The human body, and, in fact, every animal tissue, opposes to the electric current a resistance so great that in comparison with it the resistance of the elements is insignificant. It results from this, that . . . . the intensity of the current is solely determined by the number of the elements. Thus the electro-therapeutist will not obtain a stronger current with forty elements as big as a tumbler than with the same number of the size of a sewing-thimble. It is quite otherwise when one employs electricity for the purposes of cauterization by heating to redness a short and fine conducting wire which offers but a feeble resistance. In this case the resistance of the elements need alone be considered, and their number will not increase the intensity of the current. In this case our end is attained by increasing the surface of the plates.’

There are several terms used in speaking of electricity which seem to be hardly well chosen. Thus, the words *Intensity*, *Quantity*, *Tension*, and *Density*, are never-failing stumblingblocks, for they are used in an arbitrary and not always reasonable manner; and as it is impossible to explain any one of them without having recourse to the others, it happens that electricians are not always in accord with regard to their exact definition. Our business here, however, is not to reform electrical nomenclature, but to explain as clearly as we can the existing names.

Intensity, as we have said, is dependent primarily upon the electro-motive force (which we have spoken of as the propelling power of the current), and secondarily upon the resistances which that force encounters. Intensity is the measure of the quantity of electricity which flows through a section of the circuit in a given time. By multiplying the number of elements we do not increase the so-called quantity of electricity, although, as it were, we increase its force and enable it to overcome resistance. Suppose that r is very great, and that we are employing a Daniell's element (which has just half the electro-motive force of Grove's element), then we get the same increase of intensity either by using two Daniell's instead of one, or by substituting a Grove for the Daniell.

Quantity, on the other hand, is quite independent of the *number* of elements, but depends entirely upon the surface of the plates.

We may get some idea perhaps of the meaning of these terms by comparing electricity to a bullet fired from a gun. If we double the charge of powder or improve its quality we increase the power of the bullet to overcome any resistance with which it meets, although we do not thereby increase its quantity. If, however, without altering the charge we double the size of the bullet, we do not increase its power of overcoming resistance, but we obviously double its quantity.

When we have a number of elements arranged in a series, the collecting plate of the first being joined to the generating plate of the second, and so on, we have an arrangement capable of overcoming great external resistance, and the battery is said to be arranged for resistance. Suppose, however, that instead of uniting the elements in a series, we connect all the generating plates together and all the collecting plates together, then we transform our series of elements, as it were, into one big element, and by decreasing their number we increase the area of the plates. In this way we get a great quantity of electricity. Thus we may arrange a battery for quantity, or for overcoming external resistance. In the medical batteries the elements are so arranged by the manufacturer that their re-arrangement is beyond the control of the medical man, and we are always compelled to employ two separate batteries for electro-therapy and for the galvanic cautery. Whether we shall ever have a battery whose elements will admit of a re-arrangement, and which can be used for a double purpose, is more than we can say; but with big stationary batteries, such as those supplied by Messrs. Elliott, such an arrangement might surely be contrived, and in this opinion the talented practical electrician Mr. Becker coincides. The Leclanché element is of no service as a generator of heat for the cautery.

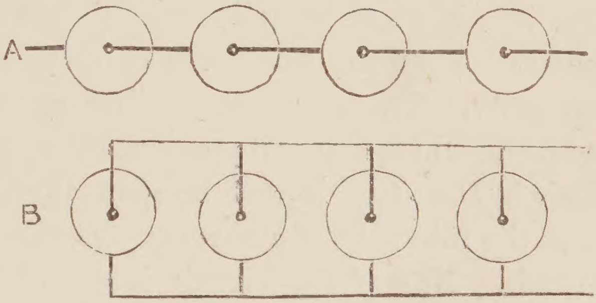

FIG. 2.—A. Battery arranged for overcoming resistance; B. Battery arranged for quantity.

There is another term in common use among electricians, and that is *Tension*. Tension has been defined as the tendency of the electricity accumulated at the poles of a battery to free itself and overcome obstacles. It may be measured by the spark which flies across a column of air interposed between two poles. The tension of frictional electricity and of induction coils is infinitely greater than that of galvanic electricity. In galvanic batteries one cannot have tension without intensity; but it is quite possible to have considerable intensity with very little tension. When we make an arrangement for overcoming external resistance we combine intensity and tension, but when we make an arrangement with large elements united by a good conductor we get intensity with very little tension. Tension depends not only upon the arrangement of the plates, but also upon the electro-motive force, and by combining a large number of small elements of low electro-motive power we get the maximum of tension with the minimum of intensity. There is still another term which is occasionally used and which it is of importance the reader should understand. This is *Density.* It will be remembered that we stated above that the intensity of a current was the same in all parts of the circuit. Now if the circuit is completed by a copper wire of uniform size, the density of the current will be the same in all parts of the wire, but if part of this wire have only half the sectional area of the rest, then the density in that part will be twice as great as in the remainder. Other things being equal, the density bears an inverse proportion to the sectional area of the conductor.

Having discussed some of the principles involved in the construction of galvanic apparatus, we shall now proceed to speak of the principles involved in the construction of induction apparatus.

Induction is of two kinds, voltaic and magnetic; and currents generated in both of these ways are frequently employed in medicine. The principle of voltaic induction is simply this: that conductors traversed by electric currents induce electric disturbance in other conductors in their neighbourhood. Let two lengths of insulated copper wire (*i.e.*, copper wire which has been covered with silk or gutta-percha) be coiled round a bobbin, one coil being superimposed upon the other. Then, if an electric current be passed through one of the coils, and if the extremities of the other coil be connected with a galvanometer, it will be found that at the moment of making and breaking the current circulating in the first wire a momentary current is induced in the second wire. At the moment of closing the circuit of the first or inducing wire, the current in the second wire is in an opposite direction to that of the inducing current. At the moment of opening the inducing circuit, the induced current is in the same direction as the inducing current.

These induced currents are only appreciable at the moment of making or breaking the inducing current, and not during its continuance.

If any medical induction coil be taken to pieces it will be seen to consist of two distinct parts: (1) a galvanic battery of one or two elements, and (2) the coils. The best element to form the battery is probably the 'Grenet,' composed of carbon and zinc plates, the exciting fluid being a solution of bichromate of potash to which some sulphuric acid has been added. A large-sized Leclanché element also serves admirably as a current generator for induction apparatus. The coils are two in number; the inner one is fixed, but the outer one is movable, so that it can be made to slide over and conceal the inner one at will. The inner coil is composed of comparatively few turns; the outer coil is composed of a far greater number of turns. The wire of the inner coil has a diameter five or six times as great as that of the wire composing the outer coil. The diameter of the coils themselves differs, that of the inner being necessarily much less than that of the outer which slides over it. The inner coil is provided with a brass tube which can be drawn over it at will. The inner coil is connected with the galvanic element; the outer coil has no communication with it whatever. There is always an arrangement by which the element can be set in action at will, or by means of which connection between the element and the primary coil can be established or broken. The inner coil has in its interior a core of soft iron wires. Surmounting the core of iron wire in the interior of the inner coil is a hammer or 'contact breaker,' the vibrations of which become audible immediately the apparatus is set in action.

All these separate points, which are observed in an ordinary induction apparatus, are worthy of consideration. First, then, the inner or primary coil is composed of a shorter length of wire of greater diameter than that which composes the outer coil, and this inner coil alone is in connection with the battery. It is this inner coil that forms the circuit for the inducing current, and the comparative short length and large diameter of the wire of which it is composed is for the purpose of keeping the intensity of the inducing current at a maximum by opposing to it the least possible resistance. But, it will be urged, the one element of this battery (be it Leclanché or Grenet), with a circuit of *straight* wire equal in length and diameter to that composing the primary coil, is incapable of giving any shock at the moment of making and breaking the circuit, and yet this primary *coil* is capable at the moment of interrupting the current of giving a very appreciable shock indeed. This shock which is given by the primary coil is due to the so-called *extra current*, which depends on two things: (1) the induction caused in each spiral of the coil by the cessation and commencement of the current in the spirals next it, and (2) the induction of magnetism in the core of iron wires which is in its interior. Electricity and magnetism have a reciprocal action, each inducing the other under suitable circumstances. When, therefore, the current from the galvanic element traverses the primary coil, the iron core becomes magnetic, and when the iron core becomes and ceases to be magnetic, it induces an electric current in the spirals which surround it. Thus it will be seen that the *appreciable* current in the primary coil is due entirely to induction, which is partly voltaic and partly magnetic, and this induced current of the primary coil is called the *extra current*.

Induced currents, we have said, are manifest only at the moment of making or breaking the circuit of the inducing current, so that the rapid interruption of the inducing current is absolutely necessary. This is affected automatically by means of the hammer or contact breaker, the shaft of which forms part of the circuit of the wire forming the primary coil. When the core of iron wires becomes magnetic, the head of the hammer is drawn towards it, and the circuit is broken; the magnetic condition of the core at once disappears, the circuit is then re-made by the rebounding of the hammer, and thus the constant and necessary interruptions of the inducing current are effected. The intensity of the current of the primary coil is regulated by the brass tube which slides over it. When this tube is drawn completely over the primary coil, the extra current is no longer appreciable, being annihilated as it were, by the counteracting effect of the tube, upon which all the induction power of the coil is spent. By sliding the tube over the primary coil, and by leaving a greater or lesser portion uncovered by it, the intensity of the 'extra current' can be very accurately regulated.

The current of the secondary coil is entirely owing to the inducing action of the primary coil. The intensity of the current in this coil depends upon (1) the intensity of the current in the primary coil, which may be regulated by the brass tube and the degree to which the elements are immersed in the exciting liquid. (2) The amount of overlapping of the primary coil by the secondary. When the coils are quite free of each other, there is no current in the secondary coil, and when the secondary coil completely overlaps the primary, its current is at a maximum. (3) The number of spirals in the secondary coil. The greater the number of spirals the greater is the intensity of the current, and for attaining this object the wire cannot be too fine, provided it be thoroughly insulated. Any defect in the insulation of the wire effectually impedes the efficiency of the coil.

When a patient is put in connection with either the primary or secondary coil, the current which traverses his body is a *derived current*, the derivation wires and his body forming, as it were, a loop line in connection with the wire which the primitive current traverses. This point, as well as others in connection with induction currents, will be made perfectly clear by reference to the accompanying diagrams, which are taken from M. Tripier's 'Manuel d'Electrothérapie.'

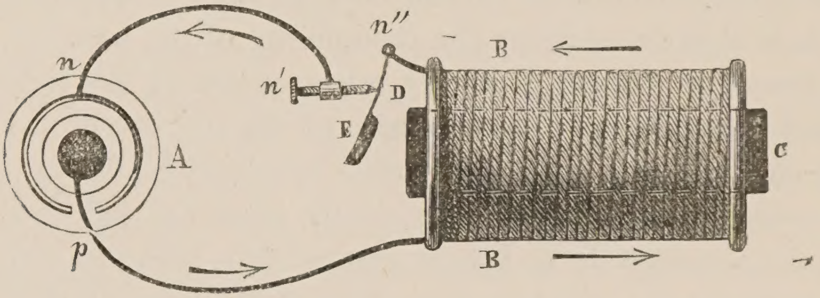

FIG. 3.

Fig. 3.—Mechanism for interrupting the current from the element.—A, galvanic element. B, bobbin on which is wound the interpolar conductor *p*, B, *n''*, *n'*, *n*. C, bar of soft iron in the axis of the bobbin. D, spring hammer forming part of the interpolar conductor. *n'*, screw pressing on the hammer so as to close the circuit.

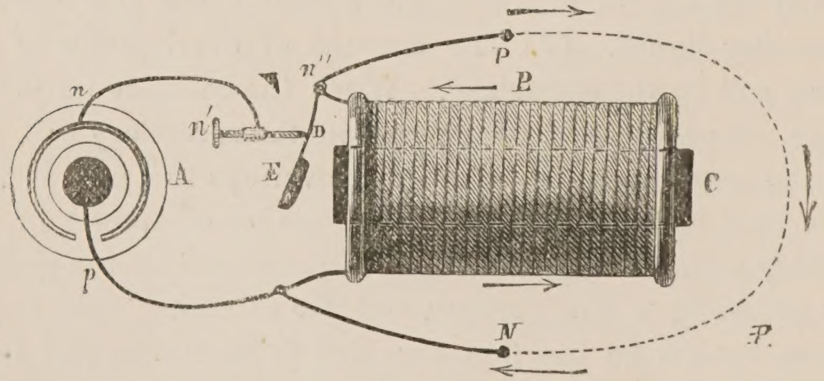

FIG. 4.

Fig. 4 shows the utilisation of the extra current. P N are the derivation wires. The dotted line represents the patient's body. The arrows show the course of the extra current at the moment of the opening of the circuit at D.

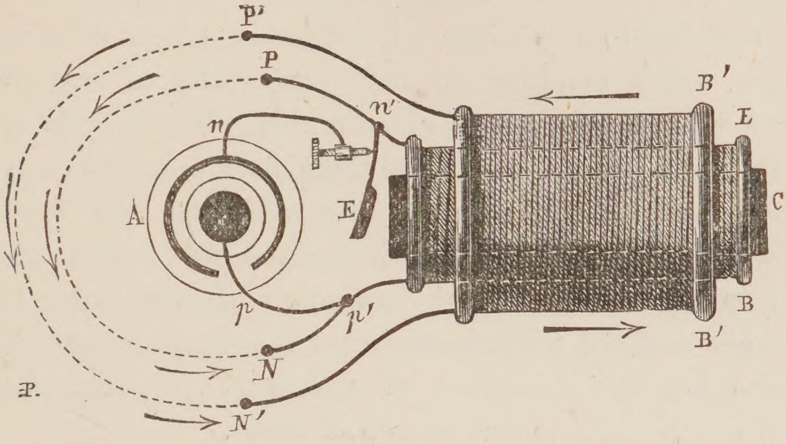

FIG. 5.

Fig. 5 shows the course of the extra current, and of the current induced in the secondary coil by its rupture.

In some batteries an arrangement is made for using the currents furnished by both coils simultaneously. This is done by joining the terminals P′ and N with a metallic conductor, while the body of the patient is included between P and N′.

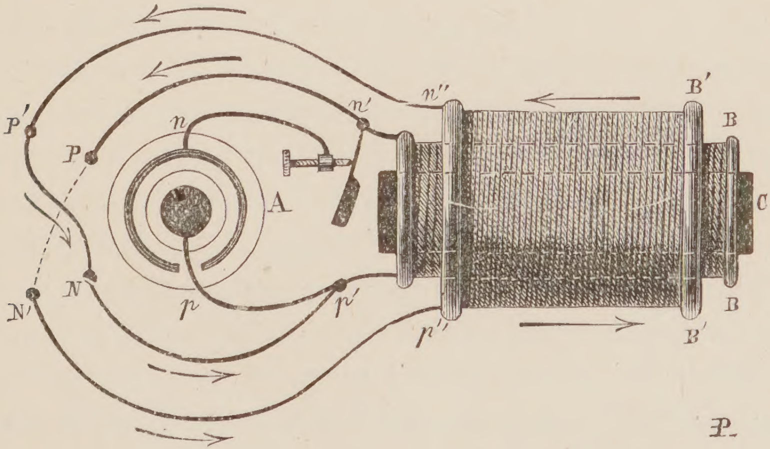

FIG. 6.

Fig. 6 shows the method of using the two currents simultaneously, with the direction of the current at the moment of opening the circuit.

The power which magnets have of inducing electrical currents has been abundantly made use of in medicine, and has furnished us with the rotary magnetic induction machine which has become a piece of tolerably common domestic furniture. This machine consists essentially of two coils of insulated wire, having cores of soft iron. These coils can be made to rotate rapidly, so that their soft iron cores can be brought alternately in contact first with one and then with the other of the poles of a horse-shoe magnet. The soft iron cores coming in momentary contact with the poles of the magnet are endued with momentary magnetic properties, on the accession and cessation of which electric currents are induced in the coils which surround them.

CHAPTER II.

BATTERIES.

Having, let us hope, brought clearly before the mind of the reader the chief of those electrical principles which underlie the construction of Galvanic and Faradic apparatus, we are now in a position to consider the question, 'Which are the best batteries for medical purposes?' We have no intention of inserting a regular trade catalogue of apparatus, which tends merely to confusion instead of instruction, but we will endeavour to impress upon the reader certain facts in connection with batteries, which will enable him to go into the market with his eyes open. A galvanic battery which is to be of service to a medical man, and which will enable him not merely to treat, but to increase his clinical knowledge of disease, should have the following points.

1. *Constant Elements.*—We had almost written Leclanché elements, so impressed are we with the superiority of these over all others which have hitherto been invented. When the circuit of the battery is open, the Leclanché elements undergo no waste, and by employing them we are enabled to dispense with any apparatus for raising the plates of the elements out of their exciting liquid. Next to the Leclanché, the most constant element we have is probably the modified Daniell, known as the Becker-Muirhead element. This element, from its large size, is not readily portable. Smee's elements have enjoyed a considerable reputation for comparative constancy, and so also have Stöhrer's zinc-carbon elements. The one drawback of the Leclanché element is this, that when the cells become exhausted it is necessary to send them to the manu-

facturer for repair. Practically, it will be found that all other elements require to be sent to the manufacturer, and while the Leclanché will require sending once every two or three years, most other kinds of elements require looking to every two or three months, and, especially in hospitals, even oftener. If neither the Leclanché nor the Becker-Muirhead element be employed, the battery must be furnished with a *lifting apparatus* for freeing the elements from the acid. If by any accident the elements be left immersed for a few days, cleaning, re-amalgamation, and re-charging will probably be necessary before the battery can be again employed. The best lifting apparatus is that devised by Messrs. Weiss, whereby the trough containing the acid is moved upwards by means of levers attached to the lid of the case containing the battery. The lid can be raised to a right angle without immersing the elements, so that any manipulations with the screws, &c., can be effected without the risk of wasteful action in the cells. When the lid, however, is thrown completely back the lever comes into action, and the tray containing the cells is raised so that the elements are immersed. To Messrs. Mayer and Meltzer belongs the credit of having devised an arrangement by means of which only those cells which one wishes to employ are immersed; and since in their battery one is left free to select any cells in the series, their arrangement is a most economical one, and one which insures the comparative utility of the battery for a great length of time.

One great advantage of Weiss's arrangement, and also of Mayer and Meltzer's arrangement, is this, that the lid of the battery cannot be closed unless the elements are free of the liquid, and thus there is little risk of their being left in a state of immersion and forgotten. In Stöhrer's batteries the vessels containing the dilute acid are raised by the hand, and fixed in position by a catch-button. For reasons stated above it is important to look to the position of this button before the battery is put away after being used.

The next question which arises is—'What size should the elements be?' A reference to Ohm's law will convince the reader that there is no object in having large elements, and if due regard be had to practical considerations (as to manageability, &c.), we should say that the elements ought to be as small as possible. We further think that there is this disadvantage in having large elements, that the shock of the current to the patient becomes more painful. We believe that some physicians still hold that large plates are an advantage, but we are not aware upon what grounds, whether theoretical or clinical, such a statement is made. The area of the plates in Weiss's Smee battery is about two and a half square inches, and the smallest Leclanché elements are about the same size. The author has had one of Weiss's batteries so arranged that the lid can be retained at any angle, and the amount of immersion of the plates regulated to a nicety. By having the elements small, portability is increased and cost diminished.

Next, as to the number of elements which a battery should contain. This can be decided only by experience. The number should be considerable, for the purpose of overcoming the large resistance of the body. It must be regulated also by the electro-motive force of the elements employed, to which it must bear an inverse proportion. We think that a battery should not have fewer than fifty elements, if Smee or Leclanché be employed. One advantage arising from having a large number of elements is, that when some of the series have become weakened by use, others can be used to supply their place. To sum up what we have been saying, we may assert that a practitioner's battery, which is intended for observation and diagnosis as well as treatment, should contain *at least fifty small-sized constant elements.*

There are two points of great practical importance in the manufacture of batteries. One is the exclusion, as far as is possible, from their composition of brittle materials, such as glass and carbon, and the next is the careful securing of the elements, by providing them with a cover, from all accidental contamination by dust or other foreign matter which may fall into the cells.

2. A battery ought to have *ample means of regulating the strength of the current.* This is effected in a variety of ways: (1) By connecting one of the poles of each element with a dial provided with a number of conducting buttons, when by rotating the arm of the dial the circuit is made to include any number of the elements we may desire. (2) Another common method of bringing about this end is to suspend the elements by pairs to a horizontal bar, along which a sledge, carrying the connecting screws, is made to travel. By moving this sledge one way or another, it becomes easy to include any number of elements in the circuit. When the current is regulated by the inclusion of varying numbers of elements in the circuit, it is important that this should be effected as gradually as possible, and that the increments should be by one or at most two elements at a time. In one battery which we have seen the increment is by five elements at a time, which is too much, since many patients who require a current from, let us say, more than five elements, are unable to bear a current furnished by ten elements.

If the action of galvanic elements were absolutely constant we could regulate the intensity of a current with perfect accuracy by the number of cells included in the circuit. Although the Leclanché element approaches more closely than any other to constancy, it is not absolutely so, and it becomes necessary, especially for physiological and other accurate experiments, to have some means of regulating and measuring the intensity of our currents with perfect certainty. For almost all purposes the sensations of the physician or the patient are amply sufficient, but for experiments requiring exceptional accuracy it is necessary to be provided with a *galvanometer* for measuring, and a *rheostat* for regulating the intensity of the current. The amount of deflection of the galvanometer needle is a measure of the intensity of the current. If we know that so many cells of a freshly charged battery in perfect action ought to cause the needle to deviate so many degrees, we may judge by the lessening amount of deviation of the needle the amount of deterioration which the activity of the battery has undergone. The small galvanometers attached to some portable batteries are of very little, if any, use.

The *Rheostat* is an instrument by means of which measured amounts of resistance may be inserted into the circuit; and since the intensity of the current is, *cœteris paribus*, inversely as the resistance, it will follow that the greater the resistance in the circuit the less will be the intensity of the current. The rheostats in most common use are those known as Siemens' and Mayer and Wolff's, and although they differ in constructive details, in principle they are the same. They consist of boxes containing a series of coils of fine insulated wire, the resistance offered by which being compared to a standard unit admits of exact numerical enunciation. These boxes contain resistance coils equal to a certain number of units, and by a very simple arrangement any number of these units of resistance may be included in the circuit. It is evident that we have in the rheostat a means of regulating the intensity of our current, which for exactitude and mathematical accuracy is unrivalled. In physiology and electro-therapy it is not easy to diminish the intensity of the current by interposing resistance coils, because of the enormous resistance offered by the animal tissues themselves. Five centimetres of nerve are said to offer a resistance equal to 1,000 metres of copper wire of the same diameter. To sensibly affect a circuit which includes any animal tissue, it is evident that we require a rheostat of enormous capacity. To avoid this difficulty a simple manœuvre is resorted to. This consists in presenting a choice of paths to the current by dividing and then reuniting the conductor. We must direct attention to the accompanying diagram.

Let A B D be a galvanic circuit, A being the element and the current travelling in the direction of the arrows. Let the conductor at B divide into two parts, of equal diameter, E and C, which reunite at D. The intensity of the current in E and C will be inversely proportional to the resistance, and since the resistance in each is equal, their diameters, lengths, and specific resistances being similar, the intensity of the current is equal in each. Suppose we double the resistance in E (and we may remind the reader that this may be done by doubling the length of E, or by halving the sectional area, or by substituting for the material of which it is composed a theoretical something which has the same length and diameter, but twice the specific resistance), then the intensity of the current in E will be diminished one-half, and the intensity of the current in C will undergo a proportional increase, for it must be borne in mind that intensity is the same in all parts of the circuit, and the sum of the intensities in the ramified portion must equal the intensity in the undivided portion.

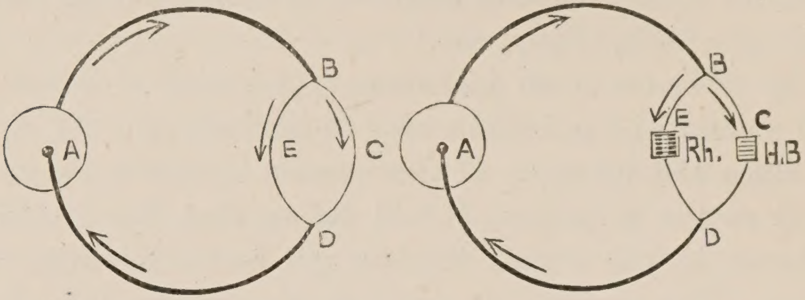

FIG. 7.

Suppose that the branch C of our circuit includes the human body or a portion of animal tissue (H B), and suppose the branch E includes a certain resistance (Rh) exactly equal to the resistance in C, but which we can increase or diminish at pleasure—such a resistance, in point of fact, as we find in the rheostat—then it is evident that by increasing or diminishing the resistance in E, we diminish and increase respectively the intensity of the current traversing that branch of the circuit, and by so doing cause an increase or a diminution of the intensity of the current traversing the other branch. Duchenne uses a liquid rheostat, which consists of a column of water contained in a tube, which is inserted in the circuit, and by a very simple arrangement the length of the column of water which the current has to traverse can be varied at will, and the intensity of the current thus readily regulated.

3. An indispensable addition to every battery is a *key and commutator*, which enables the circuit to be made and broken without altering the connections of the conductors, and which further allows either pole of the battery to be placed in connection with either conductor at will. It is at once a tap and a reverser for the current. Its construction varies, but it consists usually of a wheel or cylinder, the sides of which are in contact with the poles of the battery, and are also connected with the terminals of the conductors. The wheel is composed partly of vulcanite and partly of metal, and is furnished with a handle, by means of which it can be made to revolve. When the vulcanite portions of the wheel are in contact with the poles no current passes, and the circuit is said to be open, but by causing the wheel to revolve ninety degrees in either direction the circuit is closed ; and, further, the direction of the current through the conductors can be regulated by causing the wheel to revolve either to the right or the left, so that what is the positive pole of the battery can be instantaneously converted into the negative, and *vice versâ*, without altering the position of the rheophores on the patient's body. For studying the action of the different poles and the effects of direction of current on therapeutic results, this apparatus is absolutely necessary. No practitioner's battery should be without it.

4. Another accessory of great importance is a *rheotome*, or interrupter of the current. Slow interruptions may be effected by means of the commutator, but for rapid interruptions a cogged wheel is necessary.

Dr. Gowers has devised an ingenious pedal rheotome and commutator, by means of which all necessary interruptions and reversals can be made with the foot, leaving both hands free for any manipulations required on the patient.

We may sum up our remarks on batteries in this, that *every 'practitioner's battery' should consist of not less than fifty small constant elements of low electromotor power, and should be furnished with a regulator, a key and commutator, and a rheotome.*

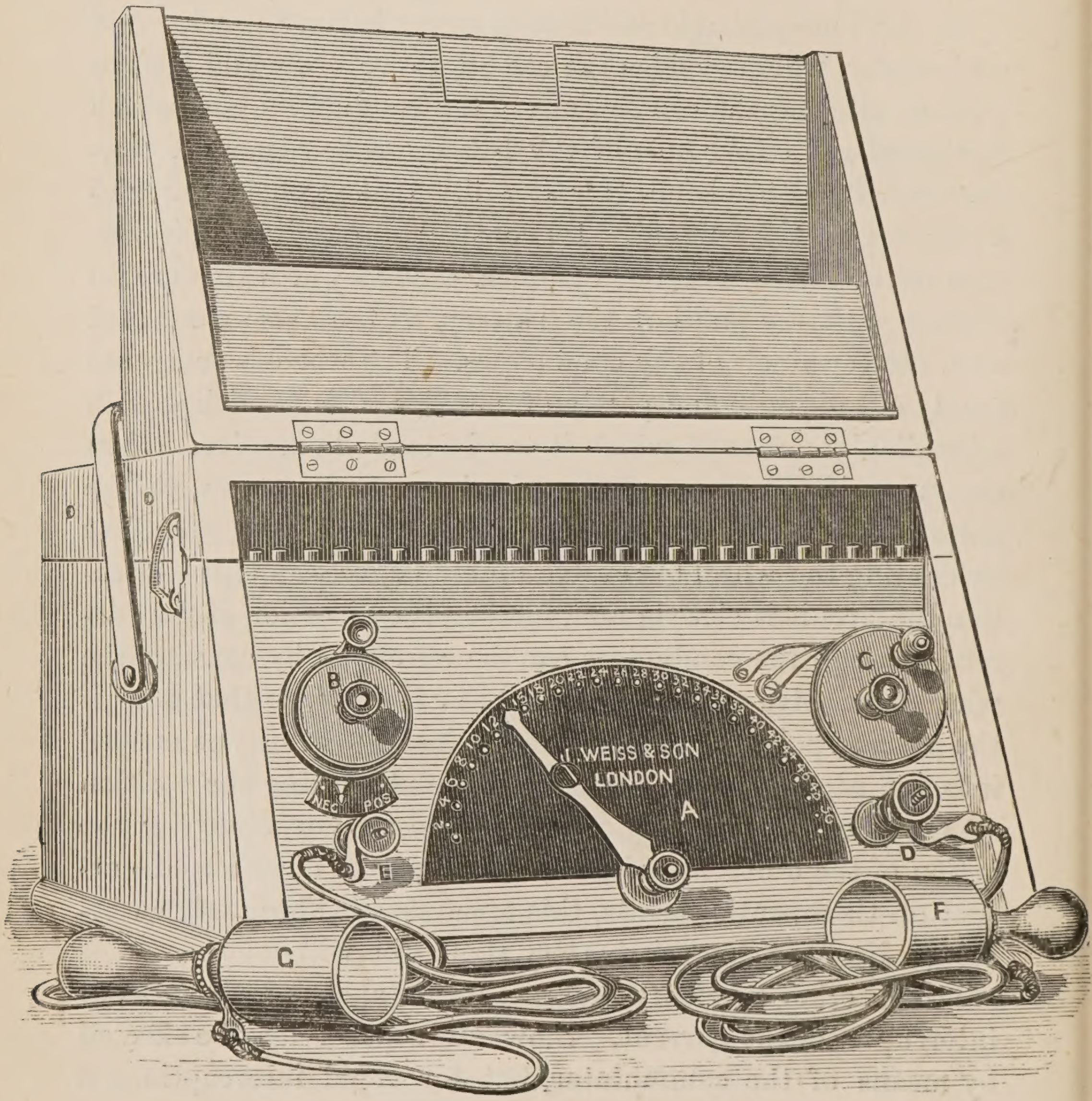

FIG. 8.—Weiss's Leclanché battery of 50 elements. A Regulator. B Commutator. C Interrupter. D E Connecting Screws. F G Rheophores (the rheophores represented are not such as the author recommends).

We believe that one of the most useful batteries which has yet been made is the Leclanché battery, manufactured by Messrs. Weiss, a figure and description of which we subjoin.

We also give figures of the Foveaux-Smee battery, made by the same house, showing the arrangement of the elements, the cells, and the mode of elevating the tray containing them, as well as the arrangement for regulating the degree of immersion of the elements.

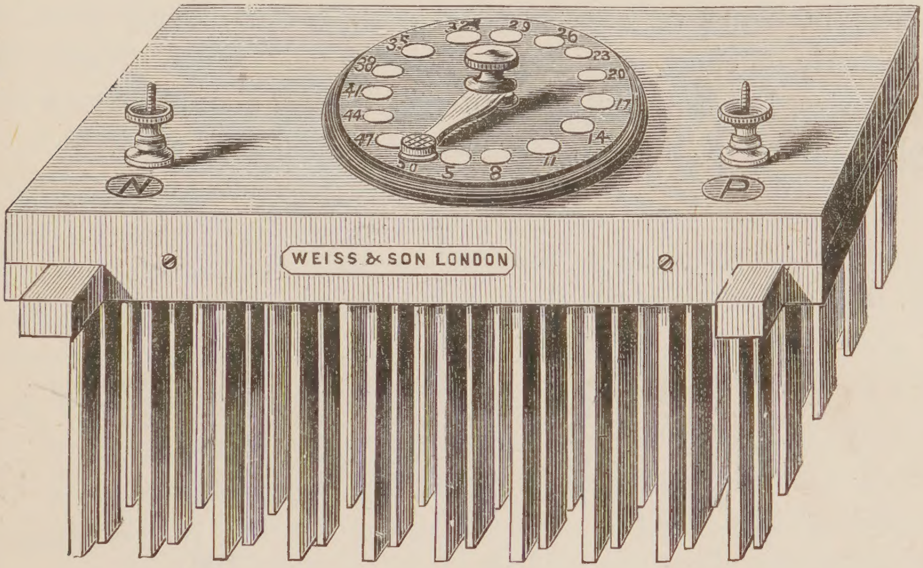

Fig. 9. Foveaux-Smee battery.—The elements, consisting of plates of zinc and platinised silver (Smee's principle), attached to an element-board, with cover and dial or regulator.

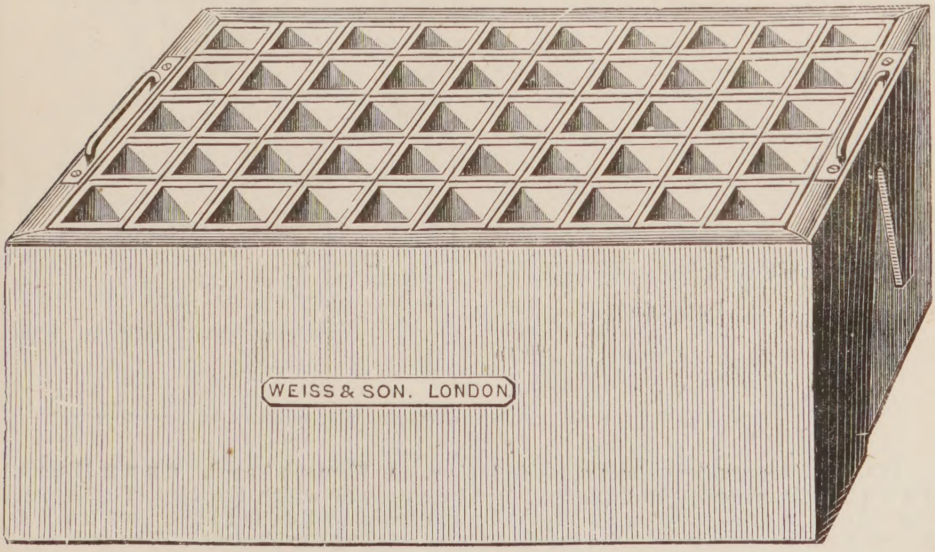

Fig. 10. Foveaux-Smee battery.—The tray containing the cells.

A battery which is intended for the use of patients cannot be too simple in its construction. In it commutator and interrupter may be dispensed with, and the number of elements need not exceed twenty. We have seen a small Leclanché battery of twenty elements, made by the India-rubber Company, which seems to us admirably adapted for the use of patients, being very strong, very simple, exceedingly portable, perfectly efficient, and little liable to get out of order. All batteries, but especially patients' batteries, should have a few plain directions as to management inserted in the lid.

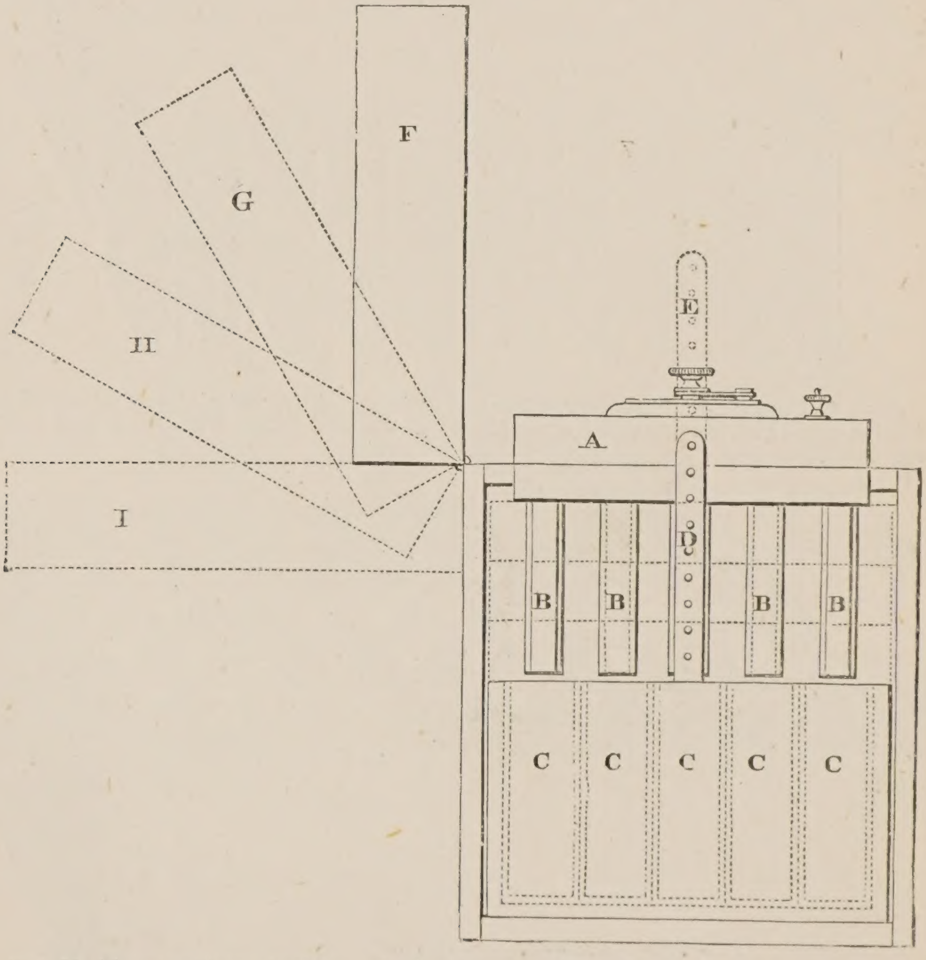

Fig. 11. Foveaux-Smee battery.—End view. A Element board. B B B B Elements. C C C C C Cells arranged in tray. D E Rod by means of which the tray of cells can be maintained in any position, as shown by the horizontal dotted lines. F G H I Lid at different angles according to the degree of immersion of the elements. The tray of cells is raised by a compound lever attached to the lid, which is not shown in the drawing.

With regard to the qualities and accessories which should be possessed by induction apparatus, we may say that they should have—

1. *Well-insulated coils.* This is an important point, and when buying an apparatus of this kind it is well to look to it, for there is much difference with respect to the care with which the copper wires are "served" with their silk coverings. The coils should be covered with a layer of varnish of some kind, as the rubbing off of the silk covering is thereby greatly hindered.

2. *Means of including in the circuit either the primary or the secondary coil, according to the wish of the physician.* This should be effected without changing the connections of the conductors. Such an arrangement is very simple, and is found in most induction apparatus. One of the connecting screws is in contact with one terminal of both coils, while the other screw is provided with a conducting lever by which it can be connected with the other terminal of either coil at will.

3. *Means of interrupting the primary current.* This should be done automatically by means of a hammer which is attracted by the central magnet as often as the circuit is closed. —(See Fig. 3.) This piece of apparatus is called the *hammer*, or the *interrupter*, or, in consequence of its exceedingly rapid action, the *trembler.* It is of importance, for the ends of exact scientific observation, to be able occasionally to regulate accurately the rapidity of the interruptions. The only interrupter which admits of anything like exact regulation is, as far as we know, that supplied with Stöhrer's large induction apparatus. This is done by screws which regulate the distance of the hammer from the magnet, and which further regulate the tension of a spring, the power exerted by which has to be overcome by the magnetic attraction. If a Stöhrer's battery be set in action one hears the interruptions vary according to the regulation of the screws. At one time they may be slow enough to be counted, sounding like the distant clacking of a mill-wheel, at another time they become so rapid as almost to simulate the buzzing of an insect's wings.

4. *Means of graduating the intensity of either current.* This is done (1) by immersing the elements more or less deeply, and so regulating the power of the cell. This will have an effect on both currents. (2) The primary coil should be provided with a brass or copper cylindrical sheath, by means of which the tension of the extra current can be regulated; and (3) the secondary coil should admit of being moved over or away from the primary coil.

In the magneto-induction apparatus the intensity of the current is regulated by the power of the magnet, which is governed by the position of the armature. When the armature is in contact with the poles of the magnet, the magnetism induced in the cores of soft iron around which the coils are wound is *nil*, and according as the armature is removed from the magnet, the intensity of the induced currents gradually increases. The interruptions are regulated at will by the rapidity with which the handle is turned. Magneto-induction coils have the great advantage of being cheap and of being little liable to get out of order; but they have the disadvantage of requiring two people to work them instead of one, and of being occasionally noisy in their action, and are therefore often a great annoyance to an invalid. Manufacturers might surely overcome this latter objection, and if the rotation of the magnet could be effected by means of a treadle, or by clockwork, the former would disappear also.

All batteries and all induction apparatus which are intended for therapeutic purposes must be provided with *conducting wires* to allow of the patient being included in the circuit. These conductors should be as perfect as possible, *i.e.*, they should offer a minimum amount of resistance to the passage of the current. They should, therefore, be made of a material having a low specific resistance, such as copper, and it is evident that their diameter should be as great as is compatible with perfect pliancy. They should be further thoroughly insulated, so that if they come in contact with conductors the current suffers no diminution of intensity. Their insulation is generally effected by means of a serving of silk or woollen material, which admits of great pliancy, and is a sufficiently good insulator, but not being waterproof the woollen covering is liable to become saturated with water, and then, of course, the insulation at once suffers.

Ordinary telegraph wire, which is copper wire covered with gutta-percha, makes a most excellent conductor, and its insulation is not liable to suffer even after months of use. It is less pliant than the silk-covered wire, which is its only disadvantage. It allows one, too, a certain amount of independence, which is always agreeable, for with a few yards of telegraph wire on hand, we can cut our conductors any length we choose, and with a little ingenuity we can always make our own connections, which is often a very great practical advantage. Telegraph wire opposes a minimum amount of resistance to the current—in this respect offering a great contrast to the ordinary conductors. Another advantage is its great cheapness. The author invariably uses telegraph wire in preference to all other forms of conductor. Some of the common magneto-electric machines are supplied with conducting wires which are not insulated at all. Such conductors are of no use.

We shall not at present speak of *rheophores*, or current carriers, which is the generic name by which the various sponge-holders and other apparatus for applying electricity to the body are known. They will be more fitly discussed when we come to speak of the modes of applying electricity.

Before leaving this part of our subject we have to make a few practical observations on batteries and the manner of looking after them. The reader will find in Dr. Tibbits' excellent work on medical electricity many practical hints on this subject.

Batteries should be so constructed that, when in use, all accidental contamination of the elements by dust may be prevented. If dust fall into the cells, local action is liable to be set up, which rapidly causes the deterioration of the elements.

London dust is a body so complex, and of such variable chemical constitution, and withal so plentiful, that it cannot be too rigidly excluded from the cells of a battery.

Again, cleanliness is, one need hardly say, of the greatest importance for the well-being of a battery. Dirt of all kinds, and especially if it be of a greasy nature, very rapidly impairs the conducting power of the apparatus. All binding screws and connections should be kept absolutely clean, and when they get tarnished Dr. Tibbits recommends that they should be scoured with emery paper. After using a battery, be sure it is clean before putting it away, and above all, be careful not to leave the elements immersed. This last caution does not of course apply to the Leclanché element.

It is particularly to be borne in mind that any moisture about a battery may impair its action, by destroying the insulation of the individual cells. Always, therefore, keep a battery dry ; be very careful in charging a battery not to spill any of the liquid between the cells, and especially be careful not to over-fill the cells, for any overflow when the elements are immersed may destroy the insulation. When moving a battery from place to place, it is important to be careful not to spill any of the liquid in the cells. One very common cause of a temporary failure of the Becker-Muirhead is the condensation of liquid on the edges of the porcelain cells, thus impairing their insulation. A knowledge of this fact becomes important, for the very simple process of wiping the damp edges with a dry cloth will at once set the battery in action again.

It sometimes happens, naturally enough, that the apparatus gets out of order and gives no current. It is then of great importance to be able to determine whether or no it requires to be sent to the manufacturer for repair, or whether its ailment is such as can be remedied by some simple measure.

One may test a battery by trying its effect upon some sensitive part of the skin or the tongue, or by trying to elicit a spark by holding the conductors near each other, or by completing the circuit, and then listening attentively for a hissing sound in the cells. This is only audible in zinc-acid batteries. If we feel the current, or see a spark, or hear the hissing, then we may be sure that the battery and conductors are all in good order. These are only coarse tests, but such as a man can at once apply in his own consulting room. If we get none of these reactions, then it is evident that something is wrong, and it becomes necessary to determine what. It may be that the conductors are at fault, and when the silk-covered conductors are used, this is by no means an unfrequent cause of failure. To test this, complete the circuit with each of the conductors singly and by turns. If we get a reaction with one conductor, but not with the other, then we know that the one with which we fail is at fault.

If we get negative results with the conductors, it may be that both are at fault, a fact which can be easily determined by testing the battery with a conductor which is certainly in order, such as a poker, which may be laid across from one pole to the other. If we still get no result, then the fault is elsewhere, and we shall find that the battery wants re-charging with acid, or perhaps some of the plates are broken, a fact which is determined on inspection. Possibly after re-charging we may hear the hissing sound in the cells, even when the poles are not connected. This is due to "local action" on the zincs, and shows that they require re-amalgamating. Amalgamation is easily effected, thus: In the first place wash the zinc, and remove from it all impurities; then pour into a saucer some dilute sulphuric acid and a little mercury, and amalgamation is then quickly accomplished by rubbing the mercury over the zinc by means of a piece of wood covered with wash-leather. The newly amalgamated zinc should be allowed to dry before it is replaced in the cell.

The non-action of induction coils may be due to exhaustion of the galvanic elements, which, as in the last case, may require re-charging or re-amalgamating.

Another common cause of failure is the faulty insulation of some of the turns of the coils. When buying one of these batteries, it is important to see that there is no friction between the coils and tubes which slide over each other. In a battery belonging to the author the friction of the brass tube on the primary coil rubbed off the silk covering of the wire, and from this cause the primary coil acted irregularly within a week of its leaving the manufactory. Covering the bare spot with gutta-percha soon remedied this, and for the past eighteen months it has given no trouble.

A frequent cause of failure in induction coils is to be found at the hammers. The more complicated they are the more liable they are to derangement, owing to the wearing out of the springs. A complicated hammer, however, is often a necessary evil, and for exact observation will be found indispensable. The part of the hammer which impinges against the screw, and the point of the screw itself, are both usually coated with platinum, and this platinum is liable to oxidation. When the oxide accumulates it is necessary to remove it, which may be done with a piece of emery paper or with the point of a knife.

It is very requisite to become acquainted with the anatomy, physiology, and diseases of batteries, and it is recommended that—once at least, if not always—the possessor should take them to pieces, clean them, charge them, and re-amalgamate them for himself. Much practical knowledge of electricity may be learnt by so doing.

It is much to be regretted that manufacturers of electrical apparatus are not agreed as to the best form of binding-screw and connection. They all have their own, and as a consequence the apparatus sold by A is often of no use when we come to apply it to B's battery. English makers might at least come to some agreement on the matter, and it would be a great advantage for them to do so. As pointed out above, however, the use of telegraph wire as a conductor enables one to make a connection with every conceivable rheophore or binding-screw.

Before leaving the subject of batteries, it is due to Messrs.

Mayer and Meltzer to mention the ingenuity which they have displayed in combining a galvanic battery and an induction coil in one box. It is often very useful to have them so combined. It will be found when we come to speak of questions of diagnosis, that the two currents are often needful at one and the same time, and the advantage of being able to take to the bedside of a patient a portable apparatus which contains all that can be required is undeniable. The obvious criticism on such an arrangement is this, that if one part of the apparatus is thrown *hors de combat* or has to be sent away for repairs, the whole concern being one and indivisible, the sound portion has to be sent likewise.

The therapeutic employment of Frictional, Static, or Franklinic electricity has become almost entirely obsolete in this country, so that in a practical work it is not necessary to devote much space to its discussion. Franklinic electricity has been of undoubted service, and when it was deposed in favour of the almost exclusive use of induction currents, there can be little doubt as to the retrogressive nature of the step. It seems probable, however, that continuous galvanic currents are capable of effecting all that can be done by *charges* of static electricity, and that induction currents are more potent for particular cases than were the *shocks* of static electricity, which at one time it was the fashion to administer.

Franklinic electricity is usually generated by the friction of a revolving glass disc or cylinder against leather cushions coated with mercurial amalgam. The disc becomes positively and the cushions negatively electrified, and a patient insulated by being placed upon a stool or sofa with glass legs, becomes charged with positive or negative electricity, according as he is connected with the prime conductor which collects the positive electricity from the disc or with the cushions. The machine must be absolutely dry to give satisfactory results. Such results are difficult to attain in this damp climate. As accessories to the machine, Leyden jars were used, and even

Leyden batteries which were capable of giving most powerful and even dangerous shocks accompanied by sparks. If a patient be charged with static electricity, and a good conductor be held near the body, sparks fly from the body to the conductor. The difficulty of getting the apparatus to work properly, as well as its unwieldiness and costliness, have, in addition to the reasons above given, caused the discontinuance of its employment.

CHAPTER III.

PHYSIOLOGY.

WE purpose devoting this chapter to a consideration of the physiological relations of Electricity, but before touching upon that subject, it will be both convenient and necessary to make a few remarks upon the two forms of electricity we have been considering.

In Dr. Walter Smith's work on the uses of Electricity the differences between these currents are very concisely stated. With regard to the *galvanic current* we must bear in mind—

1. That the current is continuously evolved, and that it always flows in one definite direction. This is a point which requires attention, because, not only is the effect of the current stated to differ according to the direction which it takes, but the action of the two poles is markedly different.

2. That it has well-marked chemical and thermal effects. With even a mild current the skin becomes sensibly warm, and with a current of moderate strength we are able to cause redness, blistering, inflammation, and even sloughing of the skin. This action is most marked at the negative pole.

3. The constant current has *electrolytic effects*, and although we shall have more to say on this subject hereafter, it becomes necessary to briefly allude to it in this place, because there is no saying what part electrolysis does or does not play in some of the phenomena we are immediately about to discuss.

When a current is passed through a compound liquid, decomposition is frequently observed, two of the component substances being separated, one at the place where the current enters, *i.e.* the positive pole, and the other at the point where the current leaves, *i.e.* the negative pole. This decomposition is called *electrolysis*, and the substance *electrolysed* is called an *electrolyte.*

In the electrolysis of water it will be remembered that bubbles of gas are evolved at either pole, and that the quantity of gas evolved at the negative pole is double that evolved at the positive pole. That at the negative is *hydrogen*, and that at the positive *oxygen.*

If a salt is decomposed the bases appear at the negative and the acids at the positive pole.

Now, it must be borne in mind that the human body is a mass of cells, and that these cells contain and are bathed in a saline fluid. It is, therefore, impossible to shut our eyes to the fact that when a constant current is passed for some time, in the same direction, through the body, some of the phenomena observed may possibly be due to electrolytic changes in the cells composing the part acted upon, be it nerve, muscle, or any other form of tissue.

Faraday re-christened the poles of a battery, and in so doing had recourse to what is known as the two-fluid theory of electricity, *i.e.* the theory of two currents running in opposite directions. The positive pole he named the *Anode* or the *up way*, and the negative pole he called the *Cathode* or the down way. The words are now very generally used, and the reader must remember that when we speak of the *Anode* we mean the positive pole, and that when we speak of the *Cathode* we mean the negative pole.

The *induced current* differs essentially in its nature from the galvanic current.

1. It is momentary in origin and duration.

2. Its direction is constantly changing, and the positive and negative poles may change places many times in a second.

3. From these causes, as well as others probably, its chemical, thermal, and electrolytic effects are almost *nil*, so slight, in fact, that they may be entirely disregarded.

4. The intensity and tension of this current is very great, and it overcomes without difficulty any resistance which the human body may oppose to it.

5. It causes the contraction of muscles far more markedly than the galvanic current. It will be found that the galvanic current causes the contraction of a muscle only at the moment of making or breaking the circuit, and it is owing to the constant interruptions in the induced current, as well as to its great tension, that its power in causing muscular contraction is mainly due.

When we consider that the living body is composed of a mass of cells, in the majority of which chemical action is going on with greater or less vigour, and when we remember that wherever chemical action is going on, there electricity is evolved, it is not to be wondered at that we should frequently get manifestations of electrical action in the living body; and although the assertion which we so frequently read at the head of advertisements that 'Electricity is life' is certainly not true, we can have no hesitation in stating that wherever life is manifested, electricity may become manifest also. This is probably true of plants as well as animals, and the recent interesting discovery of Dr. Burdon Sanderson, that electrical disturbance takes place during the contraction of the leaf of the *Dionæa muscipula* or Venus's fly-trap, will doubtless prove the starting-point for many new discoveries in this direction.

A very suggestive experiment by Dr. Ralfe, recorded in the 'Lancet' for July 4, 1874, gives a hint as to the part which electricity may play in some of the ordinary 'vital' processes. No satisfactory explanation has as yet been given to account for the separation of the acid urine and gastric juice from alkaline blood, and with a view to the elucidation of this point, Dr. Ralfe introduced an alkaline solution, consisting of bicarbonate of soda and neutral phosphate of soda into a small U tube, fitted with a diaphragm at the bend, and passed a weak electric current through the solution. In a short time the fluid in the limb connected with the positive pole became acid from the formation of acid phosphate of soda, the salt which gives urine its acid reaction; while the fluid in the limb connected with the negative pole increased in alkalinity. The changes effected in the solution are represented by the following formula:—

Bicarbonate of Soda + Neutral Phosphate of Soda
($NaHCO_3$) (Na_2HPO_4)

become

Carbonate of Soda + Acid Phosphate of soda
(Na_2CO_3) (NaH_2PO_4)

To account for the formation of free hydrochloric acid in the gastric juice, chloride of sodium is substituted for the neutral phosphate of soda, the decomposition in this case being

Bicarbonate of Soda + Chloride of Sodium
($NaHCO_3$) ($NaCl$)

become

Carbonate of Soda + Hydrochloric Acid
(Na_2CO_3) (HCl)

Most of our exact knowledge on the subject of animal electricity is due to Professor Du Bois Reymond. His experiments were made with the help of a most delicate galvanometer, so sensitive that the most trifling currents would cause it to deviate. From these experiments it follows that there are no two parts of the body (save those which exactly correspond on the opposite side) whose electrical condition is precisely the same, and that the differences between them are greater in proportion to the difference in activity of the vital processes which are being carried on in them.

That which has especial interest for us at present is the fact that certain definite electrical currents have been discovered in muscular tissue and in nervous tissue. If an entire muscle of an animal quite recently killed—the muscles of the frog are the best for these experiments—be removed from the body and put in connection with the poles of a delicate galvanometer, the needle will be at once deflected, showing the presence of definite currents in the muscle. These currents vary in direction and intensity according to the position of the muscle with regard to the poles of the galvanometer. Now a muscle consists of a bundle of fibres having a generally parallel direction, and attached at their extremities to a tendinous structure. The tendinous portion represents a surface formed by the bases of the fibres, and this has been called its *natural transverse section.* The surface of the muscle, on the other hand, has been called its *natural longitudinal section.*

It has been found that when one pole of the galvanometer is connected with the natural longitudinal section, and the other with the natural transverse section, the direction of the current is from the first to the last. If the muscle be cut in pieces, and the natural sections, both transverse and longitudinal, be replaced, as it were, by artificial sections (no matter to what extent of minuteness this division of the muscle be carried), it is found that the direction of the current is still the same, viz., from the artificial longitudinal section to the artificial transverse section. This state of things has thus been concisely expressed :—

'Every point in the natural or artificial longitudinal section of a muscle is positive in relation to every part of its transverse section, whether natural or artificial.' The greatest amount of electrical reaction is got when the *natural longitudinal section* is placed upon one electrode of the galvanometer and an *artificial transverse section* upon the other.

If both electrodes be connected with points in a longitudinal section (natural or artificial), then that point which is nearest the centre of the muscle or fragment of muscle is positive in its relation to the point which is farthest removed from it. If both points be equidistant from the centre, the disturbance is reduced to a minimum or is *nil.* If the two transverse sections be put in connection with the electrodes, then the electrical disturbance is also at a minimum. The same thing is found to hold good with the transverse as with the longitudinal section, viz., that the points removed from the centre are positive in relation to the centre itself. The intensity of currents between points in the same section is always incomparably less than that between points in different sections. Professor du Bois Reymond has also proved, what is certainly of extraordinary interest, viz., that during contraction the natural muscular current *is diminished or disappears.*

This fact, says Dr. Carpenter, seems to harmonise with the views now in vogue as to the correlation of physical forces, 'the changes which operate to produce disturbance of electric equilibrium whilst the muscle is at rest being concerned in the development of motor power when it is thrown into contraction.'

Nerves have natural currents just as muscles have, and these currents travel in similar direction. If, then, in our description of the muscular currents the word *nerve* be used instead of *muscle*, that description will be found to hold good.

The similarity of the two currents—up to a certain point—is exact in all particulars, and it is found that these natural currents are diminished in the nerve during excitation of the nerve just as they were in the muscle during its contraction.

Electric currents have been detected upon different secreting surfaces and glands, and even between a secreting membrane and the veins returning from it. The total quantity of electricity developed in the human body must be very large, but owing to the quantity of water in the tissues, and to the absence of arrangement for insulating the electric currents, electric equilibrium is, when disturbed, at once restored again. Any free electricity, positive or negative, which may accumulate at the surface of the body is, in a moist atmosphere like ours, at once conducted away from it. We must all have observed, when the weather has been dry or during a sojourn in a dry climate, the crackling noise, occasionally accompanied by fine sparks, which is observed on combing the hair. During the act of pulling off silk stockings, which are insulators and which fit closely to the skin, similar phenomena are observable.

If the body be insulated then the electric condition of it is easily made manifest by means of a galvanometer. It is remarkable that hardly any two persons are in the same condition electrically, and nervous, irritable people are said to exhibit a more active electrical condition than persons of a phlegmatic temperament.

Cases are on record of persons who under ordinary circumstances habitually give manifestations of free electricity. In Carpenter's Physiology a Capuchin friar is mentioned, who on removing his cowl always observed a number of dry crackling sparks to pass from his scalp.

An account is also given of a lady, who for many months was in an electric state so different from that of surrounding bodies, that whenever she was but feebly insulated, as by a carpet, sparks passed between her person and any object she approached. When most favourably circumstanced, four sparks per minute would pass from her finger to the brass ball of a stove situated at a distance of 1½ inch.

The most remarkable manifestation of electricity to be found in the animal kingdom is in the electrical fishes, of which there are many varieties. The torpedo, or electric ray, is thus described by Professor Marshall in his work on Physiology:—' The electric organs consist of two compressed oval masses, lying one on each side of the head, and reaching from between the gills into the body. . . . They consist of a strong membranous investment, enclosing a soft pulpy structure, divided by septa into hexagonal columns, which have their ends directed towards the upper and under surface of the fish. Each column is subdivided, by delicate and extremely vascular partitions, into numerous separate cells, and each cell is filled with a clear fluid, of which one-tenth part is albumen with traces of common salt. . . . These remarkable organs are supplied with very large nerves, larger than any other nerves in the body, and larger than any nerve in animals of the same size. The nerves arise from a special nervous ganglion called the electric lobe connected with the medulla oblongata, immediately behind the cerebellum. . . . The electric power depends upon the integrity of the nerves connected with the electric organs. . . . Small portions of the organ connected with the body by no other part than a nerve still retain their electric power. Destruction of the electric lobe in the torpedo completely destroys the electric power. The electric discharge is excited by touching the upper and under surface of the animal. But it is said that when two exactly corresponding points on the two sides or on the same surface of the body are touched, no shock occurs, and that not even a current passes through the galvanometer. The back of the torpedo is electrically positive, the ventral surface is negative. The shocks obtained from the torpedo and other electric fishes are capable of killing small animals, and the other reactions which they give leave no doubt that the electricity developed is exactly similar to that developed by physical means. The energy of the discharge is in proportion to the size and strength of the animal. . . . A temperature of 32° F. suspends the power, which is again restored by immersing the fish in water at a temperature of from 58° to 68°; at 86° rapid and strong discharges take place, and the animal soon dies.'

There can be no doubt that the electrical power of these organs depends upon the integrity and activity of the nervous centres with which they are in connection, and the inference has been, by some, too hastily drawn, that nerve force and electrical force are identical. That the two forces are related in so far that the one most readily excites the other there can be no doubt, and that they are very closely correlated there is every reason to believe, but that they are not identical the following reflections seem to show:—

1. The rapidity of the transmission differs—that of electricity being estimated at 462,000,000 feet per second, and that of nerve force at only about 200 feet per second.

2. Nerve force is not conductible along a metallic wire.

3. Cold diminishes the conducting power of nerves for nerve force, whereas it increases the conducting power of solids or fluids for electricity.

4. The crushing or compression of a nerve destroys its conductivity. It may be, however, that the crushing of a nerve is analogous to the breaking of the copper conductor in an insulated telegraph wire.

That nerve force increases in power according to the length of nerve excited—to gather strength, as it were, as it travels—an opinion promulgated by Pflüger, is now, according to Dr. W. Rutherford, no longer tenable.

Having briefly considered some of the more important instances in which electrical currents become manifest in the living body, we turn to consider what are the effects produced upon healthy living bodies by extraneous electrical currents. The effects produced by lightning on the living body are exceedingly varied. Sometimes the person 'struck' is killed outright, and there is no indication, *post mortem*, of any injury having been done to the body either externally or internally.

The results of the lightning stroke manifest themselves generally, however, in some functional disorder of the nervous system. The sufferers may lie in a state resembling apoplexy or collapse, or they may be violently convulsed or partly paralysed. The pupils have been noticed widely dilated and the eyes insensible to light. Occasionally entire exhaustion of muscular irritability has followed the lightning stroke, and *rigor mortis* has either been absent or so transient as scarcely to be noticeable. Various physical effects have been observed; wounds by which the current has entered and left the body—veritable apertures of entry and exit; patches of erythematous redness or tracts of scorched tissue on the surface of the body; coagulated blood or ruptured blood-vessels and consequent hæmorrhages internally; the clothes have been scorched and rent, the boots have been torn off the feet, nails have been driven out of the soles of boots (this is very common), metal articles, such as watch chains, worn about the person have been fused, and more than once a steel knife in the pocket has been rendered magnetic by the passage of the current.

With a Leyden jar one can produce many of the effects of lightning on a small scale, and if a shock be given to one of the nerve trunks all the effects of bruising the nerve may be produced—pain, numbness, and even paralysis. Small animals may be readily killed by means of a Leyden jar.

The conducting power of the various tissues of the body seems to be proportional, though not entirely so, to the amount of water they contain. The best conductor is muscle. Cartilage, tendon, and nerves come next in order. Bone offers nineteen times the resistance of muscle, and the worst conductor of all is the epidermis, which varies in its conducting power according to the amount of moisture with which it is imbued. It was once a disputed matter as to whether or not it was possible to affect the brain and spinal cord through their coverings, but it is now allowed on all hands that it is not only possible but perfectly easy to do so.

We have next to speak of matters which have a more close and definite relation to therapeutics—the effect produced on nerves by the passage of the galvanic current. If a portion of a nerve be excited by the passage of a galvanic current, a change is observed to take place in the natural nerve currents. If the direction of the exciting current coincides with that of the proper nervous current, then the proper nervous current is increased in intensity. If, on the other hand, the exciting current is in an opposite direction to the proper nervous current, then the proper nervous current is diminished in intensity.

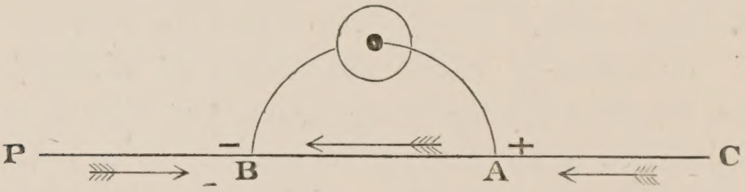

FIG. 12.

Take a length of nerve, P C. Now in accordance with the rule that we have already stated, the proper nerve current runs in definite directions, *outside* the nerve from the longitudinal to the transverse section, and inside from the transverse section to the longitudinal section. The current at the two ends P and C is then in opposite directions, indicated by the arrows. If we excite the central portion by an exciting galvanic current A B passing in the direction of the arrows, then the nervous current in the portion A C will be increased in intensity, while that in B P will suffer a decrease. It is evident that the exciting current has produced a change in the whole length of our nerve. This change is called *electrotonus.* The electrotonus produced at the two ends differs obviously. That in the portion A C in which the nerve currents are increased is called the positive phase of electrotonus. That in the portion B P, where the proper nerve current is decreased, is called the negative phase of electrotonus.

When electrotonus is excited in a nerve in the manner indicated on the diagram, certain changes take place in the physiological properties of the nerve. The part in the neighbourhood of the positive pole (the anode) on either side of it has its irritability to stimuli, and its conductivity for impressions, diminished, and this part of the nerve is said to be in a condition of *anelectrotonus.* The part of the nerve in the neighbourhood of the negative pole (the cathode) has its irritability and conductivity increased, and this part is accordingly said to be in a condition of *cathelectrotonus.*

Now, in the piece of nerve included by the exciting current, there is a *neutral spot* where anelectrotonus ends and cathelectrotonus begins. This spot is not always midway between the two poles of the exciting current, but is found to shift its position according to the strength of the current used.

With very weak currents it is close to the anode, so that in this case there is a maximum amount of cathelectrotonus in the included portion, and a minimum amount of anelectrotonus. With currents of a certain medium strength the neutral point may be midway between the two poles, and as the current gets stronger we get the maximum amount of anelectrotonus, and when this condition is reached it is found that the nerve refuses to convey stimuli, and this is called the state of *inhibition.* Thus we see that if the current be weak the conductivity of the included portion for stimuli is heightened, but if the current be strong the conductivity of the included portion is weakened.

In 'The Practitioner' for September, 1874, is contained an excellent paper by Dr. Onimus of Paris, '*On the different actions of induced and constant currents on the economy.*' His experiments have led him to consider that too much importance has hitherto been attached to the phenomena known as 'electrotonus.' 'All the phenomena observed may be explained by the fact that all organic tissues, whatever they may be, give rise to an electric current which depends upon the difference in oxidation of the two points connected by the galvanometer. Moreover, electrolytic phenomena always occur through the passage of a current, however short and weak it may be; on the other hand, derived currents are formed on every passage of a current, and immediately after the rupture of the current there occur currents of polarisation whose action, often very energetic, is the cause of the phenomena observed.'

Notwithstanding that the tension of galvanic currents is less than that of induced currents, they have a more extensive and deeper action. Deviation of the needle of a galvanometer communicating with wires introduced into the posterior limb of a large animal was observed when a galvanic current was passed through the anterior limbs. From a similar experiment on a patient similar results were obtained. By introducing platinum needles into the fore-arm, and after allowing the needle to revolve to zero, marked deviation was obtained when constant currents were passed through the upper part of the neck, or even the shoulder of the opposite side. This experiment affords proof of the diffusion of electric currents, and shows that in organic tissues the influence of a galvanic current extends in all directions, and is never limited to the two electrodes.

It was long ago pointed out that by stimulating a motor nerve contraction of the muscle supplied by it could be produced. The electric current in all its forms is the best possible stimulus for the motor nerves. The induced current, which is being constantly interrupted, has greater power in this respect than the galvanic current. The galvanic current also has power so to stimulate the nerves that contraction of the muscle follows, but such contraction of the muscles only occurs at the moment of making or breaking of the current—at the appearance or disappearance of the electrotonic state. Contraction, however, does not occur under all conditions with every making or breaking of the current, but is found to depend, not only upon the strength of the current, but also upon the direction in which the current is passing, whether *centrifugally* towards the muscle, or *centripetally* away from the muscle. If the current be travelling centrifugally it is found that with currents of all kinds (weak, medium, or strong) contraction follows the closing of the circuit.

If the current be travelling centripetally it is found that, on closing the circuit, contraction ensues if the current be of weak or medium intensity, but not if the current be strong. If the current be travelling centrifugally it is found that, on opening the circuit, contraction only occurs with currents of medium power.

But on opening the circuit with centripetal currents contraction follows only with medium or strong currents, but not with weak ones.

Now, for the sake of impressing upon the memory, we may repeat that—

With weak currents in either direction contraction only follows the closure of the circuit.

With medium currents in either direction we have contraction following both closure and opening.

With very strong currents (stronger than we dare use with human beings), with the centripetal current we get contraction only on opening, and with the centrifugal only on closure.

It is not easy to account for the universal contraction with medium currents under all conditions, but for the weak and strong current, whose action seems at first sight strangely capricious, it should be borne in mind that contraction is found to follow the appearance of cathelectrotonus, and the disappearance of anelectrotonus.

Thus, in all cases where the cathelectrotonic portion of nerve is next to the muscle, or in which the cathelectrotonic portion preponderates over the anelectrotonic, then contraction follows the closure of the circuit.

When, however, the anelectrotonic portion is next the muscle and preponderates over the cathelectrotonic, then contraction occurs only on opening.

The following scheme and diagram may assist the memory :—

Intensity of current	Centripetal		Centrifugal	
	Closed	Open	Closed	Open
Weak	C	—	C	—
Moderate	C	C	C	C
Strong	—	C	C	—

It is impossible to verify this 'law,' which is known as Pflüger's law of contraction, with any exactness on the living subject, owing to the difficulty of influencing the nerve trunks and of keeping the current within bounds when once it has overcome the resistance of the skin. This law receives, however, a great amount of confirmation from the so-called 'Polar method' of investigation which has of late come into vogue, and which we owe mainly to Brenner of St. Petersburg. If one rheophore of a battery, provided with a commutator, be placed upon some indifferent part of the body, and the other upon a nerve trunk at some point where it becomes superficial —say upon the ulnar nerve as it passes round the olecranon— we are in a position to study the action of the different poles upon that nerve.

If the current be very weak it is found that, on stimulating, a nerve contraction only occurs when the cathode is placed over the nerve, and the circuit is closed. Thus we may say that—

1. With weak currents there is contraction on cathodal closure (C. C. C.).

2. With slightly stronger currents contraction occurs when the anode is over the nerve, and the circuit is opened—anodal opening contraction (A. O. C.). If the current be slightly increased contraction occurs also with anodal closure (A. C. C.).

3. If very strong currents be used, such as we dare not use with patients, it is said that contraction occurs also on cathodal opening (C. O. C.). Thus with the three degrees of currents we get—

1. C. C. C.
2. $\begin{cases}\text{A. O. C.}\\ \text{A. C. C.}\end{cases}$
3. C. O. C.

With regard to the first of these reactions there is no doubt. The second and third seem to vary, one sometimes occurring before the other, and *vice versâ*. The fourth one we cannot attempt to verify.

On making experiments with his own ulnar nerve the author has found that the first three reactions invariably come in the order given.

It has been found that the long continuance of a constant weak current through a certain length of a nerve, will 'tetanise' a muscle connected with that nerve—*i.e.* will produce a tetanic contraction of the muscle.

The after-effects of these polarising currents are important. Experiment seems to show that the excitability of the whole nerve is strengthened. The cathelectrotonic portion undergoes a momentary negative modification, which gives place to an enduring positive modification. The anelectrotonic portion undergoes a positive modification at once.

There is no more important effect of the constant current than what may be called its *refreshing effect.* Heidenhain succeeded in restoring the excitability of the muscles of an exhausted frog by passing a strong galvanic current through them. This fact has long remained without any practical application of it. Certain observations of the author's, therapeutic as well as physiological, lead him to hope that the refreshing effects of the current will be found to be one of its most useful properties.

There are certain diseases of which we shall have more to say hereafter, and of which 'writer's cramp' is a familiar example, which are characterised by an intense feeling of fatigue on an attempt being made to perform certain muscular acts.

The author has found that this feeling of fatigue is at once removed by the application of the continuous galvanic current either along the course of the nerves or muscles of the arm. The first patient in whom the author observed the refreshing effects of the current was one who suffered very acutely from this feeling of fatigue, and always expressed great satisfaction during the employment of the current, and frequently used the words 'comfortable' and 'pleasant' to express his sensations. He also often said, '*That seems to give me strength, to give me a sense of power in the arm.*' This patient had a difficulty of supinating the hand of the right arm. There was no true paralysis, and no visible wasting of any of the muscles (though the whole of the arm and fore-arm was notably flabby, and remarkably non-muscular) ; but the act of supination was a laboured act, and the patient soon tired of performing it.

On telling him to alternately pronate and supinate the hand, these acts were accomplished tolerably well for the first four times, then the act of supination became slow, and was accomplished with an evident effort, and after four or five more attempts it became impossible; and this, as far as one could see, was not due to any spasm or paralysis. When the supination came to a standstill, the positive sponge-holder of the battery was placed as near as possible over the spot where the musculo-spinal nerve turns forward at the outer part of the elbow-joint, and the negative on the spot where the radial nerve becomes superficial on the radial border of the fore-arm. The number of elements employed was sufficient to cause an appreciable but not painful sensation to the patient. This seemed to help the supinators over their difficulty, and the patient continued to pronate and supinate his hand without the least trouble, saying at the time that 'he could do it much easier when the current was passed,' and also '*that it seemed to give him strength.*' One is not inclined to pay much attention to the sensations and expressions of a patient; and although he was an intelligent man, nothing was thought of what he said until the author found another (also suffering from writer's cramp) who said precisely the same thing, 'that he could accomplish repeated muscular acts with far greater ease during the passage of a current, and that after the employment of the current he had a feeling of strength and power in the arm.' This latter patient's expressions demanded attention, for he was a medical man, and himself accustomed to the employment of electricity. This gentleman suffered acutely from the miserable feeling of fatigue in his arm; and though his muscles were big, and he was decidedly athletic, he soon tired of repeated exercises. This tiring of the muscles and the feeling of fatigue were both obviated by the employment of the current.

From these disjointed observations the idea was got that the passage of the continuous current through muscles, or the nerves supplying them, increased the susceptibility of those muscles to the stimulus of the will, and that their voluntary power was thereby greatly increased.

The author proceeded to submit this notion to the test of experiment, and nearly every experiment made went to prove the correctness of the theory.

The first experiment was made upon the patient (H. M.) first mentioned. We asked him to hold his left arm at right angles to his body, and in the palm of the hand was placed a weight of seventeen ounces. In about four minutes (the experiment was only tentative and not exact) he complained of great pain in his muscles—deltoid, triceps, biceps, and fore-arm—and declared his inability to go on. We then placed the positive rheophore high up in the axilla, and applied the negative one to the painful parts, when he at once said, 'All the fatigue is gone, and I feel as strong as when I began.' On the evening of the same day a scientific friend kindly submitted himself to a similar experiment, and the result was the same. When the sponges were applied, he said, 'All the fatigue is gone; I feel just as though some one had given my hand a support.' One need hardly say that great care was taken not in any way to support the limb with the rheophores; in fact, in these experiments one of the rheophores at all events was generally an additional burden to the arm. The current employed was never strong enough to produce involuntary contraction of the muscles. The next experiment was made on a student of medicine, Mr. L. S. The result was exactly similar. At the end of seventy seconds he began to make complaints of pain and fatigue, which the current at once removed, and he continued to support the weight for five minutes and a quarter, declaring at the end that if we wished he could still go on. On December 6, 1873, we asked our patient H. M. to hold the weight in his left hand, and on this occasion no electricity was used. He was a man whose power of endurance was very great, and he managed to sustain the weight for *six minutes*, but endured considerable pain and fatigue while doing so. On December 7 we first galvanised the arm, and then got him to repeat the experiment, and while the experiment was in progress we occasionally passed a current down the arm and through those muscles in which any sense of fatigue or pain was developed. On this occasion he managed to sustain the weight for *thirteen minutes and a half*, a time which one would think few, if any, men could accomplish without aid. Similar experiments to these have been tried on several of the author's friends, and they all tend to show that the endurance of voluntary muscular action is enormously increased by the passage of a continuous current, and that the feeling of fatigue, both during and after the prolonged effort, is mitigated or entirely obviated. It may be that the first result is merely a consequence of the second.

Experiments have also been made, and with results which tend to show that the force, as well as the endurance, of voluntary muscular action is increased by employing a galvanic current. The muscles experimented upon have been the flexors of the fingers, the contracting force of the muscles being registered by the squeezing of a spring dynamometer held in the hand.

The person experimented upon has been directed to squeeze the dynamometer several times in succession, an interval of ten seconds being allowed between each squeeze. The force of each successive squeeze was noted, great care being taken that the position of the dynamometer in the hand and the position of the patient should remain constant throughout the experiment. Two sets of observations were made, one with and one without the aid of galvanism. The patient was directed to put out his whole strength for every squeeze. The strength of current varied in different cases (the sensitiveness of individuals varying), but was always just sufficient to cause a gentle tingling sensation along the course of the nerve which one wished to affect. In these cases it was sought to affect the median nerve, and for this end the positive sponge was placed at the inner border of the biceps muscle, and the negative on the inner side of the tendons of the biceps at the bend of the elbow. The force of each squeeze is expressed in pounds.

The following is the result of one of several experiments made by the author upon himself. The figures show the result in pounds of each successive squeeze:—

Dynamometer in left hand,	without galvanism .	55, 55, 55, 50, 47, 44, 42, 40 = 388.
	with galvanism .	73, 65, 63, 60, 56, 54, 53, 53 = 477.

The total results of these two experiments give 89 lbs. in favour of galvanism, or an average of 11·125 lbs. per squeeze. It should be added that the experiment with galvanism was made about ten minutes after the first, and there was distinct consciousness of the fatigue of the first experiment when the second commenced. On the following day the experiment was reversed, and the trial of strength with galvanism preceded the other. Thus:—

Left hand,	with galvanism .	73, 76, 72, 70, 70, 70 = 431.
	without galvanism	60, 47, 45, 40, 46, 41 = 279.

The sources of error in these experiments are very numerous. Great care is required that neither the position of the patient nor the dynamometer should undergo any change during an experiment. There is a certain knack required in using the dynamometer so as to get the maximum results, a knack which is only acquired after more or less practice. Some persons easily bruise the hand during experiments, and then further results are necessarily fallacious, since the pain of pushing against the bruised surface impedes the putting forth of power. A trifling variation in the state of health will cause a great variation in the strength, and a man who can squeeze with a force of 70 lbs. one day, will, perhaps, not be able to make the dynamometer register half that amount on the next. The following experiment was made upon Mr. L. S., a medical student. The row of figures shows the result of successive squeezes. The employment of galvanism was intermittent during this experiment. The black figures show the results obtained during its employment, and the light ones the results when it was allowed to intermit:—

85, 81, 72, 75, 80, 75, 76, 75, 60, 65, 54, **80, 72, 82,** 70, 76, 51, 54, **80, 80,** 67, 78, 68, 58, **81.**

This experiment shows, like the experiment with the weight, that the power of endurance is increased by the employment of galvanism.

Owing to the impossibility of separating muscles from the terminal branches of the motor nerves which ramify in them, the electro-physiology of muscular tissue can hardly be investigated apart from that of the nerves. When we come to speak of therapeutics, however, we shall find that the reactions of muscle to the various currents are of the highest importance. Muscle of all kinds—striped and plain—can be made to contract by the application of the galvanic or induced current, but especially the latter. No matter where the muscle be situated—in the limbs or on the walls of an internal viscus—provided it can be reached by the current, contraction will follow.

Faradisation of the pneumogastric—if too powerful—will arrest the action of the heart. Great caution is therefore needed while employing electricity in the neighbourhood of the trunk of this nerve.

It was once a matter in dispute, but is so no longer, as to whether or no the brain could be influenced by currents. If the reader will take the two rheophores of a galvanic battery, and place them on either side of the head, and gradually and very cautiously increase the current, he will first feel a fulness of the head, then giddiness, and lastly, if the current be too strong, will stagger and fall.

The fact is that, not only is there no doubt about the influence of the current on the brain, but that influence is so peculiar and so powerful that the greatest caution must always be exercised while using galvanic currents near the head.

Hitzig says that if a person be galvanised on the back of the head, at the moment of closing the circuit he falls on the side of the anode, and both eyes are turned towards the cathode. On opening the circuit, the reverse is observed.—(‘London Medical Record,’ March 5, 1873.)

There is also no doubt that galvanic currents can be conducted to the spinal cord through its bony and other coverings.

There can be no cause for doubting also that the sympathetic nerve is influenced by the electric current just as other nerves are; or that the muscles of the blood-vessels and other internal organs which it supplies respond like other muscles to the stimulation of their nerve.

Claude Bernard has shown that faradisation of the sympathetic causes contraction of the blood-vessels, and the further experiments of other investigators render it probable that the primary contraction gives place to a dilatation.

Legros and Onimus assert that galvanisation of the sympathetic augments the circulation. Since, of late years, the sympathetic has been made answerable for disease of all kinds, it is not to be wondered at that physicians have striven to influence the nerve with currents of electricity, and so cause contracted vessels to dilate, or paralysed vessels to contract again. It is not possible, however, to influence the sympathetic trunk in man without influencing many other important nerves as well, so that we are, as yet, almost entirely in the dark as to the effect of galvanisation and faradisation of the sympathetic.

Although, however, it is impossible to single out the sympathetic trunk in the living subject, it should be borne in mind that the electric current cannot possibly be passed through any length of the human body without the sympathetic nerve branches, in common with all other conducting tissues, coming in for their share of electric influence.

The nerves of special sense and the nerves of common sensation all react to the galvanic current.

If either of the poles be brought in the neighbourhood of the eyes, a flash of light will be noticed on opening and closing the circuit. It has been sought to distinguish between the effects produced by either pole, and by opening and closing. These have not sufficient practical value (even were they established beyond doubt) to warrant us in devoting much space to their consideration. The flash of light seems to the author to occur on every occasion, except that of cathodal opening. Great caution is necessary while applying electricity in the neighbourhood of the eyes. Only the weakest possible currents should be used, and the intensity should be increased very gradually. In Duchenne's work will be found an account of a deplorable accident which happened to that eminent physician. He employed too powerful a current to the orbital region of a patient, and had the mortification of producing permanent blindness on that side. He has himself, in a most noble manner, placed this accident on record, and it should serve as a lasting warning.

The acoustic nerve also reacts to galvanism, but it is not easy, in all persons, to produce the characteristic effects. Brenner, of St. Petersburg, who is the champion of what is now known as the polar method of investigation, has stated the effect to be as follows:—(1) That on making cathodal closure there is a noise in the ears, which gradually diminishes during the continuance of the closure of the circuit. (2) Cathodal opening causes no noise; (3) anodal closure causes no noise, but if the current be strong enough there is (4) a noise produced at the moment of anodal opening. These noises have been said to be caused either by the electrolytic decomposition of the water with which the ear on some occasions has been filled, or by the contraction of some of the intrinsic muscles of the ear.

If the noise were due to the first cause, it would hardly cease during the continuance of the closure of the circuit. If it were due to the second cause, we should expect to get a noise occasionally on closing the anode.

If the Schneiderian membrane be acted upon it is said that a peculiar smell is produced. The gustatory nerve is easily affected, and when either of the poles touches the cheek or the tongue what is known as the 'galvanic taste' is produced. The taste differs somewhat with the two poles, that with the cathode being metallic and disagreeable, and that with the anode rather more acid in character. This difference of taste with the two poles has been supposed to be due to electrolytic action, and up to this time the theory has neither been completely proved or disproved. As to this difference of taste with the two poles the author has no doubt, and, for his own part, he may say that he has never any difficulty in telling, by the taste alone, which pole is in contact with the cheek.

On the nerves of common sensation the electric current produces very decided effects, something between a burning and a pricking. This sensation continues as long as the circuit is closed, and, excepting that the sensation is rather stronger and more violent with the cathode, there does not seem to be much difference in the action of the two poles.

The cathode, if applied to the skin for a long time, produces redness, and even inflammation and destruction of it, so the cathode must not be permitted to remain stationary on the skin. The author has seen many patients who have worn galvanic apparatus continuously about their bodies, in whom very troublesome ulcerations have been produced.

The anode causes redness of the skin, but has not, with currents of ordinary strength, any destructive action.

In Sir William Gull's report on the electrical treatment of disease ('Guy's Hospital Reports,' 1851) will be found an excellent drawing, illustrative of the effect of electricity on the capillaries of the skin of an infant. It represents a patch of punctiform redness, scattered through which are a few white circular spots, and about an equal number of circular livid spots. These appearances were produced by 'taking sparks' from a patient already charged by the Franklinic machine. 'The white spots are the result of the stimulus at the points of its greatest intensity. They are slightly raised, and the papillæ prominent from the contraction of the muscular fibres of the cutis, producing an appearance, superficially observed, not unlike urticaria. This state of contraction in the cutaneous tissue is soon followed by relaxation, and a blue venous spot replaces the white. . . . The blueness soon changes to a bright rose blush.'

The physiological action of the induced current is chiefly that of an exciter of nerve and muscle. When applied to the skin it causes redness, a pricking or smarting pain, and erection of the papillæ. The reader will find in books discussions as to the difference in the physiological effects of the current of the first and second coil—of the extra current, and of the induced current. Duchenne argues that the difference is not merely one of degree, and is not simply due to the different tensions of the currents of the two coils, but in asserting this he is at variance with most other physicists and physicians. The current of the primary coil (the extra current) excites more actively, he says, the sensibility of certain subcutaneous muscles (such as the deltoid and supinator longus) and certain organs (such as the rectum, bladder, testicle, and spermatic cord). The current of the secondary coil acts more powerfully upon organs deeply placed (such as deep layers of muscles), a fact which is almost certainly due to its greater tension. It is said also to affect more acutely the sensibility of the skin and the retina. In the paper previously quoted Onimus makes the following remarks on the action of the two coils of the induction apparatus, and on the difference between induced and continuous currents :—

'The shorter the duration of a current, the more intense is the degree of excitement produced. The fact is explained by a law of electro-physiology, that excitement of a nerve or muscle depends less on the absolute value of the tension of a current than on the modification of that value from one moment to another.'

'Induction currents are always double, and occur at the moment of making and breaking the inducing current. In the primary coil or extra current the making current is so weak that it may be neglected, and the breaking current be alone considered. This is not the case with the current of the second coil, in which both the making and breaking current are of importance. This constitutes one of the chief differences in the two currents.'

'An induced current only acts during the infinitely short time of its passage, after which everything returns to order . . . . it can never be anything else but a series of slight excitements. With constant currents real excitement is determined only at the times of making and breaking. In the interval the molecular state of nerves and muscles remains in equilibrium. It is during the silent period, however, that the principal action of the continuous current makes itself felt.'

It has been proved that on the cessation of the passage of a galvanic current through living tissue, a so-called 'current of polarisation' is generated in the tissues themselves, passing in an opposite direction to the primary current.

Dr. C. B. Radcliffe has come to conclusions as to the part which electricity plays in the economy which are not in accordance with those usually received. These conclusions are thus set forth in his work on 'The Dynamics of Nerve and Muscle,' and we regret that our space does not permit us to do more than refer to the elaborate experiments and learned arguments by which these conclusions are supported.

'There is reason to believe that all kinds of electricity act upon nerve and muscle by way of charge and discharge, the *charge* antagonising, the *discharge* permitting the state of action.

'There is reason to believe that the blood acts upon nerve and muscle, not by causing the state of action, but by antagonising it.

'There is reason to believe that "nervous influence" acts upon nerve and muscle, not by causing the state of action, but by antagonising it.

'The whole case is simple enough. It would seem indeed—

'(1) That the sheaths of the fibres in nerve and muscle are capable of being charged like Leyden jars, and that during the *state of rest* they are so *charged*.

'(2) That the sheaths of the fibres in muscle are highly elastic.

'(3) That the fibres of muscle are elongated during the state of rest by the charge with which their sheaths are charged, the mutual attraction of the two opposite electricities, disposed Leyden-jar-wise, upon the two surfaces of the sheaths compressing the elastic substance of the sheaths, and so causing elongation of the fibre in proportion to the amount of the charge.

'(4) That the muscular fibres contract when the state of rest changes for that of action, because the charge which caused the state of elongation during rest is then discharged, and because this discharge leaves the fibres free to return by virtue of their elasticity simply, from the state of elongation in which they had been previously kept by the charge, and that the degree of contraction is proportional to the degree of elongation previously existing.

'(5) That the fibres of nerve are not affected in the same way as the fibres of muscle by the charge and discharge of electricity, because the sheaths of the fibres may be wanting in the requisite degree of elasticity.

'(6) That the blood antagonises the state of action in nerve and muscle by helping to keep up the natural electrical charge which antagonises action.

'(7) That "nervous influence" antagonises the state of action in nerve and muscle by helping to keep up the natural electrical charge which antagonises action.'

CHAPTER IV.

METHODS OF USING ELECTRICITY.

Up to a certain point both forms of electricity (galvanism and faradism) are applied in the same manner. The conducting wires of the battery are furnished with so-called current carriers or rheophores. The most common form is the sponge-holder, which consists of a brass conducting tube (into which a sponge may be inserted) mounted upon an insulating handle made of ebonite. The insulating handles being held by the physician, the sponge-containing tubes are able to conduct the current to the patient's body. Some old-fashioned magneto-induction apparatus are furnished with rheophores which are not insulated. Such are of no use, or rather, are worse than useless. The junction between the conductor and the rheophore is generally placed in the middle of its length, between the conducting tube and the insulating handles. This is the most convenient place for it. Some rheophores have this junction situated at the extremity of the handle—at the heel, as it were. This is an inconvenient position, because when the rheophores are held in the same hand the two conducting junctions are liable to touch each other, and the current does not then travel into the sponges. The rheophores should not be too big and unwieldy, and the handles should be slightly hollowed out, to allow of their lying with ease between the fingers. It is convenient to have the sponges fixed into the tubes securely, so that whilst sponging the surface of the body, the sponge shall not escape from the tube. For this end the author has had the tubes of a pair of rheophores perforated, and has adopted the very simple expedient of transfixing the sponge at its base with a piece of wire.

There are many varieties of rheophore, and the ingenuity of manufacturers has been largely directed to the contrivance of instruments which may be applied to every part of the body. The practitioner will find, however, that a little ingenuity exercised by himself will often render special apparatus unnecessary.

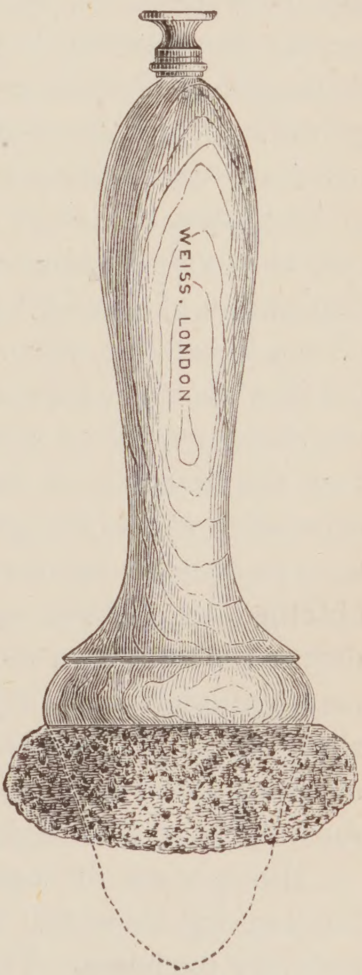

FIG. 13.

It is often convenient to have one rheophore attached to the body or to the limb of a patient, and although special band rheophores may be obtained for this purpose they will not be found more effectual than the simple plan of placing an ordinary sponge upon that part of the body to which it is wished to apply the current, placing thereupon the bared end of the conductor (which should be of telegraph wire), and making all secure with the turn of a bandage. *Fig*. 20 (p. 91) shows such an arrangement applied to the neck.

One of the best forms of rheophore with which the author is acquainted is that devised (he believes) by Kidder, of New York. (*Fig*. 13). It consists of a wooden handle, having a hollow at the upper end for the reception of a sponge, which is retained in its place by a plate, under the edges of which the border of the sponge is turned, the stem of the plate running through the handle of the rheophore, and being secured by a screw. If such a rheophore be fitted with a good cup-sponge it is a most useful instrument, since, if it be applied gently to the surface, the point of the sponge forms a rheophore of small surface for delicate work, but with a little pressure the sponge is flattened and becomes a rheophore of large surface for coarse work. The practical man will appreciate the great advantage of having a sponge securely fastened in a handle. This rheophore has its junction situated at the heel, but since it is meant to be used singly and not in pairs held in the same hand, the objection raised to this mode of junction does not apply to it.

If two rheophores be placed on different parts of the body, and if a current of a sufficient strength be employed, the skin having been previously well moistened, the current will travel through the body from one rheophore to the other. The current, galvanic or faradic, entering by one rheophore, having once overcome the resistance of the epidermis, encounters the soft moist tissues, and all of these being good conductors, it spreads out, as it were, or ramifies in them (undergoing thereby a great diminution of density) till a point midway between the rheophores is reached, when the diverging paths begin to converge till they reunite at the other rheophore. This ramification of the current causes a diminution of its intensity, so that we see that the intensity of the current is diminished by the wide separation of the rheophores. If, therefore, we wish to influence any particular region very strongly, our end is in part obtained by a closer approximation of the rheophores. The denser the current the greater is its stimulating action. We may regulate the density of the current also by the size of the rheophores. If one rheophore be of large surface and the other of small surface, it is evident that the current will be most dense in the neighbourhood of the smaller.

Rheophores do not always take the shape of sponge-holders, but these will be found the most generally useful for ordinary purposes. They are constructed of any conducting material, metal or carbon being generally employed, and are made of various sizes and shapes, according to the purpose for which they are intended. We may use our rheophores either dry or moistened. If we wish merely to influence the skin, we may use them dry; but if we wish to affect the deeper tissues, it is absolutely necessary to moisten them.

If we wish to faradise the skin, we use both our rheophores dry, or it is better to use one dry and one moist. We place the moist rheophore upon some indifferent part of the patient's body, and the dry one upon that part of the skin we wish to influence. If a very gentle effect is desired, we may have recourse to the manœuvre known as the electric hand, which we owe to the ingenuity of Duchenne. The skin should be dried and powdered, and one moistened rheophore being placed upon an indifferent spot upon the patient's body, the other should be held in the hand of the operator, who may then with the back of his hand, previously dried and powdered, stroke the dried and powdered patch of his patient's skin. The effect is a strange crackling noise, accompaned by a gentle tickling-pricking sensation. It is generally used only about the face. The finger of the operator forms occasionally a convenient rheophore for influencing the facial muscles.

If we wish to influence the skin more strongly, we may do so by means of a pointed metallic rheophore held persistently at one spot, or by brushing the surface of the skin with a metallic brush. If we wish to influence the muscles (and it is the muscles which we most commonly need to influence in electro-therapeutics), we must first overcome the resistance of the skin. Salandière was the first to attempt to influence the individual muscles, and this he did by thrusting insulated needles through the skin into the very muscles themselves—a formidable proceeding, which is, happily, no longer necessary, since the skin, by being thoroughly moistened, is converted into a good conductor. The moistening of the skin should be effected by means of *hot salt and water.* Saline solutions conduct far better than pure water, and hot water softens the skin far more quickly and effectually than cold.

The accompanying figures illustrate different forms of rheophores which have been employed for influencing different regions of the body.

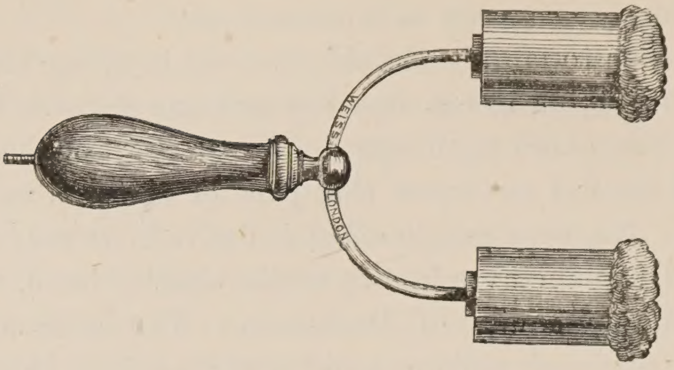

FIG. 14.—Double sponge-holder.

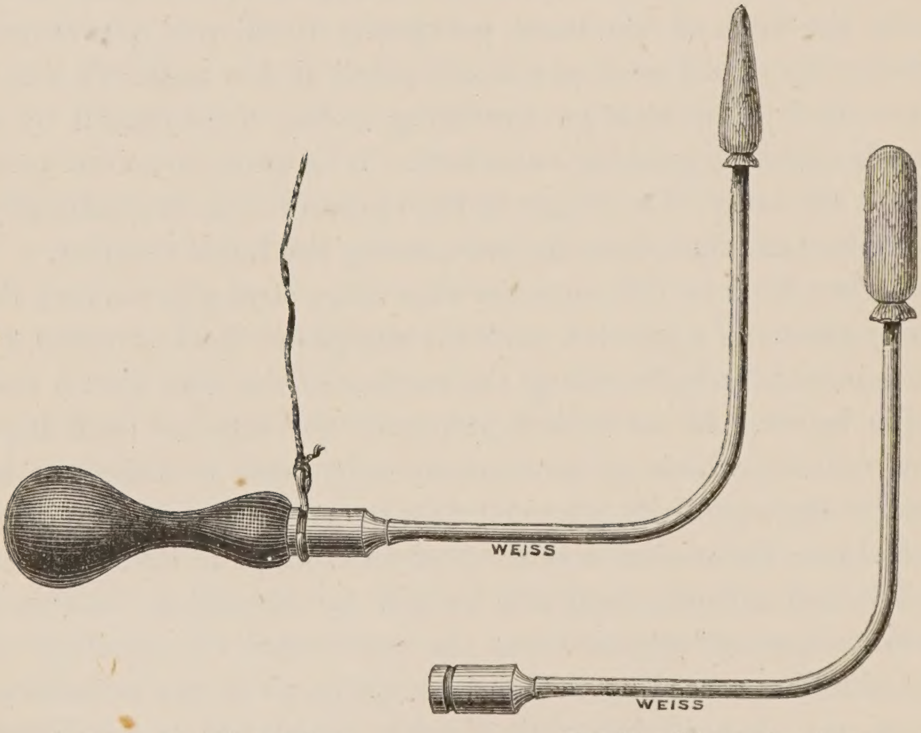

FIG. 15. –Conical rheophore.

FIG. 16.—Olivary rheophore.

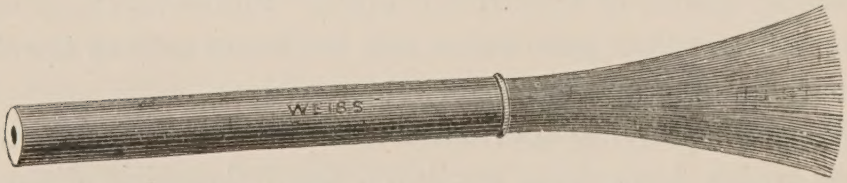

FIG. 16 *a*.—Metallic brush or threads.

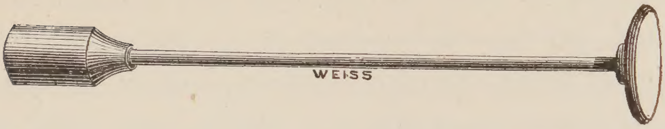

FIG. 16 *b*.—Disk rheophore, made of various sizes.

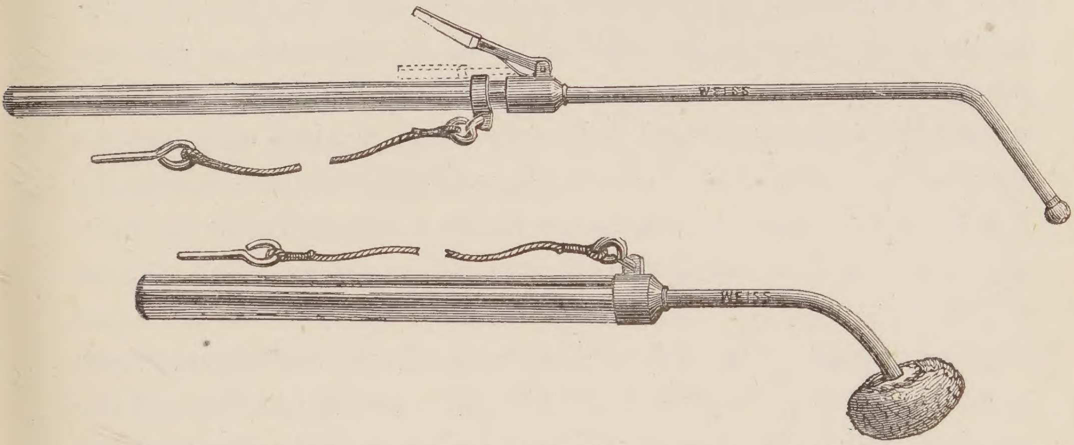

FIG. 16 *c*.—Dr. Morell Mackenzie's laryngeal rheophores.

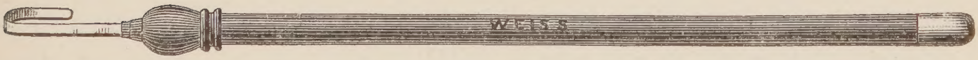

FIG. 17.—Rectal rheophore.

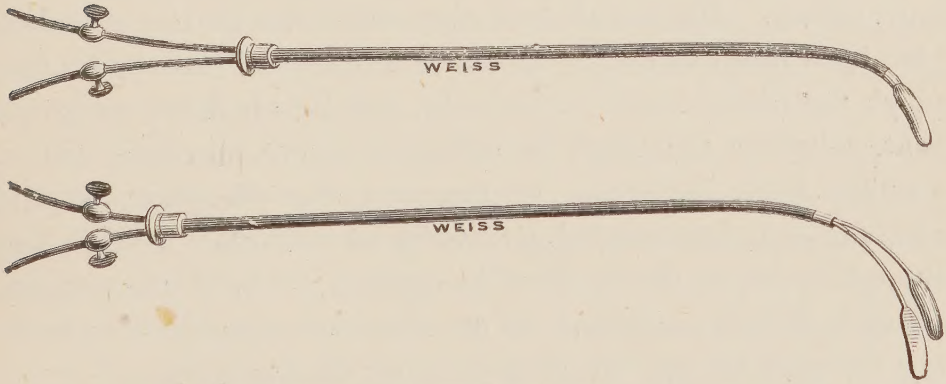

FIG. 18.—Bladder rheophore. The engravings show the instrument both open and closed.

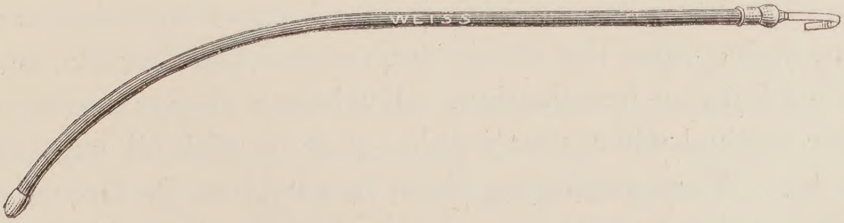

FIG. 19.—Urethral and Uterine rheophore.

How should we seek to influence the muscles? This has been a vexed point, and has been hotly disputed, and, as well as other vexed points in electro-therapeutics, has given rise to much unnecessary quarrelling. When one sees a number of careful observers on either side contending with wonderful bitterness as to whether or not the muscles are best stimulated directly or indirectly, as to whether or not the sympathetic nerve-trunk is amenable to galvanism, and as to whether the polar method or the direction method of using the continuous current is to have the preference, one is naturally led to the conclusion that there must be some right on both sides, and as a consequence, if both sides are in some degree right, they must both be—since they differ *toto cœlo*—in some degree wrong. The fact of the matter is that when once the electric current has passed the skin it is very much beyond our control, and it is quite as difficult to limit its action to a certain point as to prevent its action from influencing any particular spot. In this way, we believe, we may account for the great benefit which often follows the employment of electricity in the hands alike of polarisers, directionists, localisers, and others. Duchenne was the originator of the so-called 'localised faradisation.' In the treatment of disease he employs faradism almost exclusively, and lays it down as a rule that, whether we want to influence nerve-plexuses, nerve-trunks, nerve-filaments, or muscles, the rheophores should always be approximated as closely as possible. In this way there can be no doubt that he gets currents of the greatest possible density, and such as are therefore capable of exercising a maximum amount of stimulation on the parts.

We can influence a muscle in two ways:—(1) By acting upon the muscle itself, which is called direct faradisation; or (2) by acting upon the nerve which supplies the muscle, which is called indirect faradisation. Duchenne always prefers the former method when practicable—that is, with all superficial muscles. When employing direct faradisation, he directs that the rheophores be held in one hand, the other being left free to regulate the strength of the current. 'To completely faradise a muscle,' he says, 'it is necessary that the rheophores should cover the whole surface of that muscle, and if they are not big enough to do so, they must be applied successively to all parts of its surface. The thicker the muscle, the stronger must be the current, for if the current is feeble, the excitation of the muscle only takes place in the superficial layers.' For big muscles, such as the deltoid, trapezius, or extensors of the thigh, big sponges may be used, and these sponges should be 'promenaded' over the whole extent of the muscle. For smaller muscles, such as the interossei of the hand or foot, or for the facial muscles, smaller rheophores are more convenient. They may be flat metal discs covered with wash-leather, or they may be conical. The disc is a very useful form of rheophore, for we may use either the broad flat surface or the narrow edge.

Duchenne claims for his method that, by strictly localising the current, we run very small risks of producing general effects. It is well known that, in certain recent cases of paralysis, accompanied by active changes in the nerve-centres, faradisation, especially if not accurately localised, has produced untoward results; and it is to avoid such results that Duchenne's method is used.

The indirect method—the method proposed by Remak and worked out by Ziemssen—consists, not in stimulating the muscular fibres themselves, but in acting upon the nervous twig which is in direct communication with the muscle. In this way a thorough contraction of all the fibres supplied by the nerve is ensured; and the champions of this method further claim for it that it is more physiologically correct to stimulate a muscle through its proper channel of stimulation. In Ziemssen's work, 'Die Electricität in der Medicin,' will be found some careful drawings, in which are accurately delineated the exact points on the surface of the body at which the various motor-nerve branches supplying the different muscles are most readily accessible.

To practise this method it is necessary to have two rheophores of different shapes: one of large surface should be placed upon some indifferent part of the body, such as the sternum or the hand or the nape of the neck; the other should be olive-shaped, with a pointed extremity, and should be applied directly to the motor point. As to the motor points, there is no mystery about them; an ordinary knowledge of anatomy and a little practice will enable the practitioner readily to hit upon them.

It is not necessary for us to demonstrate all the motor points of the body, but we may give a few examples.

Thus the motor point for the anterior belly of the occipito-frontalis is found on the temple; that for the orbicularis palpebrarum on the margin of the orbit; that for the zygomaticus major at the lower border of the zygomatic arch towards its outer end, and so on, as may easily be verified.

There are many muscles in the body which are not accessible to faradisation, except through their 'motor points.' One of these muscles is the diaphragm, and since an artificially produced contraction of the diaphragm becomes of vital importance in the production of artificial respiration, it may be well to practise finding the 'motor point' of this muscle, which is situated in the neck, over the course of the phrenic nerve. To reach this point one must take a small rheophore, and push it forwards under the posterior edge of the sterno-mastoid muscle, in the lower third of the neck, and in this way we reach the phrenic nerve, which lies upon the scalenus anticus, and is covered by the posterior border of the sterno-mastoid.

The motor point for the supinator brevis, another muscle which cannot be directly faradised will be found on the back of the forearm, near the radial border, nearly corresponding in position with the head of the radius, but a little below it. With regard to these two methods, we may say that neither of them should be exclusively employed, and that sometimes the one and sometimes the other will be found the most convenient. The indirect method is apt to be very painful, if the current be too intense, but it is a method which is indispensable in the case of certain deep-lying muscles, and in cases where we wish not only to test the excitability of the muscle itself, but of its motor nerve also.

Duchenne speaks of *reflex faradisation.* By this he means faradisation of muscles with the rheophores widely separated. If the rheophores be held one in either hand, it will be found that contraction of certain muscles of the fore-arms will result. It was very common a few years ago, and is still not uncommon, to find patients who have furnished themselves with magneto-electric machines, which they used by holding the rheophores in the hands, and sending the strongest possible currents through the body. Such a proceeding is at once clumsy and unscientific, and may be followed by disastrous consequences in cases of recent paralysis with centric changes. We are not aware of any circumstances in which such a method of using electricity would be justifiable, except in cases of hysteria, drunkenness, or opium-poisoning. The reflex effects of faradisation are sometimes very peculiar. We have met with one patient—a gentleman—in whom the mildest currents of faradisation produced nausea.

Duchenne mentions the case of a girl suffering from complete left hemiplegia, in whom faradisation of the paralysed side (although she was completely unconscious of it) caused giddiness, vomiting, flashing before the eyes, and a pain in the left breast. Faradisation of the healthy side produced none of these effects.

He mentions also the case of a medical student, suffering from recent left hemiplegia, and who sought to cure himself by reflex faradisation, holding a rheophore in each hand. As a result, apparently, of this unwise manœuvre, he was tormented for many months with tetanic spasms of a most painful kind.

There are several processes known as 'general faradisation.' Thus the feet may be placed in a basin of water connected with one rheophore, and the hands in another basin of water connected with the other rheophore. In this way the whole body is traversed by the current. Messrs. Beard and Rockwell, of New York, are accustomed to stand their patients upon a metallic plate connected with one rheophore, while the operator holds the other rheophore with one hand, and rubs the patient's body with the hand which is still at liberty. If we wish for a more general faradisation (or galvanisation) we may immerse the whole body in a bath connected with one rheophore, and touch some non-immersed part of the body with the other. The author, however, is not acquainted with any condition in which such a practice would be likely to be of any use. 'Central galvanisation' is effected by placing one rheophore on the back and the other at the epigastrium.

What we have hitherto been saying is mainly applicable to faradisation.

There are certain points in the employment of galvanism which require special mention. All the differences of method in employing galvanism as distinguished from faradism arise mainly from the fact that the current flows continuously in a definite direction, and has very decided chemical and thermal effects, especially at the negative pole.

The galvanic current may be employed continuously, or it may be used interruptedly. If employed continuously, we must take care that the current is not too intense, and that the negative pole is not placed upon too sensitive a part of the skin, otherwise we shall produce inflammation and blistering at the spot where it is applied.

If the current be rapidly interrupted it becomes far more perceptible to our senses, and a current so weak as hardly to be felt may become almost painful if rapidly interrupted. The sensations caused by the galvanic current are of two kinds: (1) the stimulating sensation, not unlike that of faradism, due to the variations in intensity, or the interruptions of the current; and (2) the burning sensation due to the chemical and thermal effects of the current.

When both rheophores are kept perfectly stationary, it has been spoken of as the *stabile* method of using the current. If, however, one pole be kept stationary (say the positive), and the other (the negative) be moved over the surface of the skin, this is called the *mobile* method.

If the galvanic current be employed for stimulating muscles to contract, it must be interrupted; for the reader will remember that contractions only occur at the moment of making or breaking the circuit. For stimulating muscles, the direct or the indirect method may be adopted, and the same considerations as to the size and the position of the rheophores hold good as with faradism. The interruptions may be effected by constantly removing or replacing one of the rheophores; but this is not a good plan if we wish accurately to observe the excitability of a muscle. It is better to leave the rheophores *in situ*, and make the interruptions by means of a commutator or a cogged wheel. Some authorities lay great stress upon the direction which the current takes, either *down* the limb (the direct current), or *up* the limb (the inverse current). The former is said mainly to influence motor nerve-fibres, and the latter sensitive nerve-fibres. We are not aware that these assertions are founded on any well authenticated facts. The facts have certainly not come under our own observation.

It is well to try an experiment. We shall see that if we place the positive pole in the axilla, and the negative over the ulnar nerve, on closing the circuit we stimulate the ulnar nerve, and get contraction of the muscles supplied by it. If we reverse the current, and make the axillary rheophore the negative pole, then, on closing the circuit, we get much more movement; for the arm is flexed at the wrist and elbow, and the hand is supinated. This is an apparent contradiction to the assertion that the descending current has most power in stimulating motor-nerves. The real explanation is that, in the first instance, the cathode exerts its influence only on one nerve—the ulnar; while in the second instance it stimulates all three cords of the brachial plexus.

Brenner denies the possibility of guiding the current in certain directions into a nerve, except in a very few instances, and he says that the apparently different effects are due to the position of the poles, and not the direction of the current.

Brenner has probably a great deal of right on his side when he asserts that *pole* has more influence on the effects obtained than direction.

The polar method, pure and simple, may be practised by placing one pole upon an indifferent part of the body, and applying the other to the part we wish to influence. If we wish to cause irritation at a part we apply the cathode, and if we wish to allay irritation we employ the anode. This polar theory is undoubtedly right as regards the fact that cathodal closure is a powerful stimulant, but the soothing effect of the anode is more doubtful.

Benedict, of Vienna, lays great stress upon the position of his rheophores, and he distinguishes several varieties of current. Thus, if one rheophore be placed upon the spinal column and the other on a nerve or muscle, he distinguishes the currents as *spinal nerve currents* or *spinal muscle currents*; or if one rheophore be placed on the nerve and the other on the muscle, he speaks of it as a *nerve muscle current*. We may imitate him, and distinguish these currents by letters—S.N.C., S.M.C., N.M.C.,—which will be found convenient when making notes of cases. He lays it down as a rule that the *locus morbi*, be it brain, spinal cord, nerve, or muscle, should always be included between the rheophores.

There is one method of using galvanism which the author believes is almost exclusively practised by himself. This is *the combination of a continuous galvanic current with voluntary muscular exercise*. There are many cases—as the reader will find when we come to speak of therapeutics—in which, without any paralysis in the ordinary sense, there is considerable impairment of nervous or muscular activity; and it is in these cases that the above-mentioned method has been found of great and undoubted use. If one wishes to influence a certain muscle or group of muscles, we polarise the nerve supplying it or them with a very mild galvanic current, so as to produce a maximum amount of cathelectrotonus on the polarised part. In this state a nerve has its irritability and conductivity for stimuli increased. Cyon, by polarising his ulnar nerve with a weak descending current, and stimulating the portion of nerve below the cathode with the faradic current, found that with the same amount of faradism there was increased irritability and activity of the nerve (as measured by the contractions of the adductor of the thumb) when the circuit of the current was closed, than there was before its closure. The excitability of the nerve for artificial stimuli was increased. If for artificial stimuli, why not for mental stimuli also? The author's clinical observations seem to point to the fact that during the passage of the polarising current the voluntary mental stimulus acts with greater effect on the muscles, or, in other words, the contracting power ot the muscles is increased. This increased activity on the part of the muscles is a fact of which he has no doubt. The true explanation is, however, more doubtful, It may be due to the electrotonic condition of the nerve, or it may be due to the action of the current upon the vaso-motor nerves and the consequent change brought about in the nutritive activity of the muscles or nerves.

The great power which the galvanic current has upon the peripheral circulation (whatever may be its influence upon the circulation of central organs) is a fact of which nobody who has, even to a small extent, employed electricity can entertain a doubt.

Since great results are said by some to have arisen from the galvanisation of the sympathetic nerve we must devote a short space to its consideration. It is usually accomplished by placing one rheophore on the inner side of the sterno-mastoid muscle, over one of the sympathetic ganglia (which are on a level with the third, fifth, and seventh cervical vertebræ), the other being placed on the back of the neck. It is, of course, impossible to single out the sympathetic by such a manoeuvre as this, and any current passing between the rheophores placed in the positions we have indicated must influence not only the sympathetic but also the trunks of the glossopharyngeal and pneumogastric nerves, as well as the superior laryngeal branch of the latter. The spinal accessory and hypoglossal nerves must also come in for their share of stimulation; but it must be conceded to those who advocate the galvanisation of the sympathetic, that the nerve cannot escape being influenced by currents passed in this direction. The author has 'galvanised the sympathetic' many times, but beyond the occasional dilatation of the pupil (which is by no means an inevitable occurrence), he has never seen any indication of the nerve responding to the stimulus. He has never seen unilateral pallor, which ought (if our notions as to the vaso-motor functions of the sympathetic be correct) certainly to be a common result. Dr. Buzzard, Mr. Brudenell Carter, and Mr. Netten Radcliffe have carefully examined the fundus oculi during the so-called galvanisation of the sympathetic, but have never observed any change in the calibre of the retinal vessels. Other observers, however, state that they have seen such results. Galvanisation of the neck must be practised with great caution, since giddiness and faintness occasionally are produced, and while using currents in this situation we must increase their strength very gradually, and pay unremitting attention to the sensations of the patient. Acts of swallowing and coughing, especially when the negative rheophore is on the neck, are generally produced, the latter phenomenon being caused probably by the irritation of the superior laryngeal nerve. When 'galvanising the sympathetic' we occasionally get the so-called 'diplegic contractions' of the upper limbs, *i.e.* slight convulsive movements, which remind one of a postman's knock, by their double character. This, however, is a very rare phenomenon.

Cyon says that the best way to influence the sympathetic is to place both rheophores along the spinal column.

The galvanisation of the sympathetic is used especially in cases which seem to indicate disordered circulation in the nerve centres, brain, spinal cord and ganglia. Benedict says, 'One knows how important is the vascular activity of the brain; and, in fact, one can in general say that the health of the brain is in proportion to the health of its vessels, and that its functions are normally performed only if the functions of its vaso-motor nerves are normally performed also.'

There is a method of using galvanism which we owe to Dr. C. B. Radcliffe, a method which is in scientific accord with the opinions held by that physician, that the neurilemma and sarcolemma are charged with positive electricity; but of which method, as regards its practical application, we know very little that is definite. It is known as *Radcliffe's positive charge*, and is thus accomplished. The patient is insulated by being placed upon a sheet of gutta-percha or a glass-legged stool. The rheophores are then applied to his body, and a conducting wire is connected with the negative rheophore, and taken 'to earth,' that is, it is put in connection with some good conductor, such as a gas pipe. In this way the patient is, electrically speaking, in a maximum state of positivity; the negative electricity being conducted away by the ground wire.

For influencing the various parts of the body a variety of apparatus has been devised, some of which we have depicted.

Fig. 19 is a rheophore, shaped like a catheter, which can be passed into the bladder in cases of paralysis of that organ. If we wish to influence the bladder we may pass one rheophore into its interior and place the other upon the surface of the abdomen, above the pubes, or else we may employ a bougie, containing two insulated conductors, which, when it has passed through the urethra, can be protruded from the end of the instrument, and so touch both the walls of the bladder (*Fig.* 18).

Fig. 16 is an olive-shaped conductor for inserting into the rectum. *Fig.* 17 is for the same purpose.

A rheophore like a funnel-shaped ivory sheath, along which a conductor may be passed into the ear, has also been made. Dr.

Morell Mackenzie has devised a clever instrument for faradising the larynx (*Fig.* 16 *c*). It is shaped like a catheter, so as to be passed with ease through the glottis, and by means of a little key in the handle, the connection with the instrument is made and unmade with the greatest readiness. It would, of course, be impossible to pass the apparatus through the highly sensitive larynx if the faradic current were circulating. Dr. Mackenzie is accustomed to connect the other pole of the faradising battery with a pad, which is fastened over the thyroid cartilage by means of a collar.

Rheophores, both single and double current, are made for the uterus on the same principle as those made for the urethra and bladder.

A few words may be added on the application of Franklinism. We have mentioned before that the patient being previously insulated, may be connected either with the prime-conductor (in which case he is charged with positive electricity), or with the rubber (in which case he is charged with negative electricity). The first form of Franklinisation has been spoken of as the electro-positive bath, the second form as the electro-negative bath.

If, when a patient is charged with either form of electricity, a conductor, and especially a pointed conductor, be brought near his body, a spark will escape from his body to the conductor. Another method of startling a patient is to give him a shock from a Leyden jar, but, in the words of Dr. Reynolds, 'short of being hanged' one cannot imagine anything much more unpleasant.

CHAPTER V.

DIAGNOSTIC USES OF ELECTRICITY.

On commencing this subject, one cannot do better than quote a passage from the work of Professor Meyer, of Berlin. He says: 'As by the use of the stethoscope and the plessimeter, the diagnosis of pulmonary and heart diseases has attained a scientific certainty, and the therapeutic processes, based upon the physical examination of the organs affected, have become rational, in like manner the treatment of paralytic cases has had a more scientific basis ever since we have been able, by means of that delicate reagent, the electric current, to examine the nervous and muscular irritability of the parts affected. As, however, the physical examination of the thoracic organs, without consideration of other indications, supplies in but very few cases the attainment of a sure diagnosis, and never for the establishment of a rational cure, so, too, the electric current is only an auxiliary, which, when we have fully considered all the symptoms peculiar to the individual, ... will, in many obscure cases, assist us to a surer diagnosis.'

By a judicious employment of electricity we are enabled to determine the degree of irritability of muscle and nerve, and to determine whether or no this is in excess or is diminished. This is effected with the greatest certainty, when we are able to compare a muscle or nerve on one side of the body with its healthy fellow on the opposite side, for in health it will be found that the irritability of symmetrical muscles and nerves is the same on both sides of the body. To decide this we must proceed with great care, for it is no very easy matter to be sure that in successive applications of electricity the intensity of the current is the same. When, therefore, we wish to compare the irritability of muscles on opposite sides of the body we must attend to the following points :—

1. Place the patient comfortably in a chair or in bed, and be sure that his attitude is such that the two halves of the body are arranged as nearly as possible symmetrically.

2. Be sure that the current which is applied to the muscles on either side of the body travels through equal lengths of the body, so that the resistance offered to the current shall be the same in both cases. To insure this it is advisable to fasten one rheophore to the middle line of the body, and in the author's experience there is no more convenient spot than the nape of the neck.

3. Be sure that the muscles upon which we wish to operate are both in a condition of absolute repose.

4. We must use a sponge of large surface for the stationary rheophore, while a small conical rheophore, covered with wash-leather, is applied to the nerves or muscle which we wish to test.

5. Be sure that the skin is thoroughly and equally moistened on the two sides.

6. It is well to begin with the healthy side, and having determined the least strength of current which, when applied to the muscle or the nerve supplying it, will produce a contraction, we then proceed to apply the same current to the diseased nerve or muscle, and watch the result.

The following sketch represents the mode pursued by the author in testing the irritability of the dorsal interossei muscles.

If the muscles on both sides of the body are in an unhealthy condition, it follows that a comparison of the two sides will give no satisfactory results. In such cases it is necessary to compare the muscles to a healthy standard, which is generally to be found in the memory of any physician of tolerable experience. This method is necessarily far less exact and satisfactory.

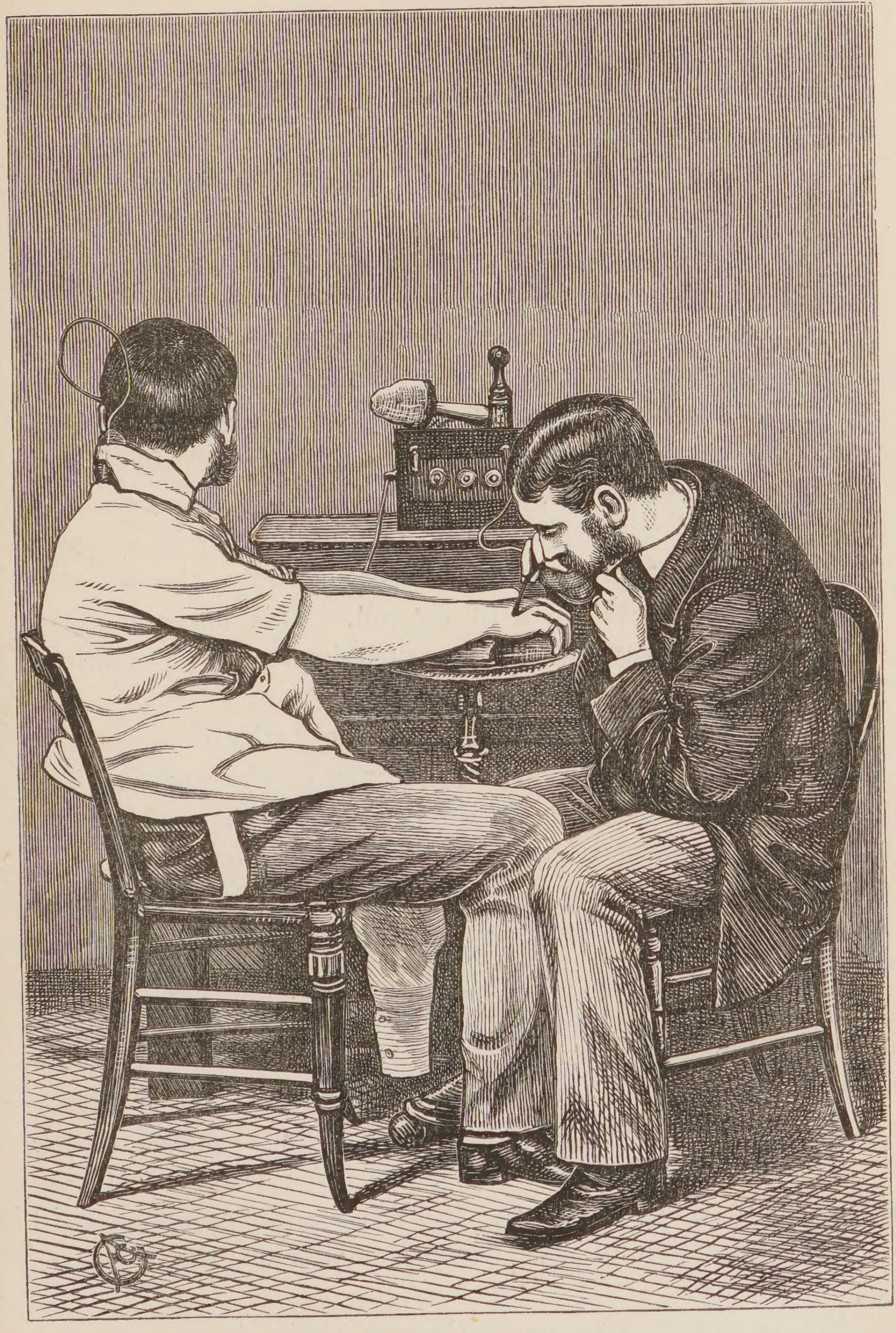

FIG. 20.

In many obscure cases of loss of the power of movement of any muscle or group of muscles, the electric reactions of the muscle or nerve are often of the greatest use, and serve not unfrequently as the main basis of a diagnosis, but more frequently to settle a diagnosis in cases where a consideration of the other circumstances has left a certain degree of doubt.

It will be convenient to recapitulate the causes which may act in producing want of power in a muscle.

1. Want of education. This would seem to be the main reason why most of us are unable to move the muscles attached to the lobes of our ears, and, according to physiologists, the power of moving them is to be acquired by taking thought and by diligent practice.

2. Want of will. The nerves or muscles may be in a state of health, but their possessor may not have the requisite force of will to set them in motion. This is the condition apparently in many cases of so-called hysterical or emotional paralysis.

3. The will may be perfect, but the paths of nerve-force between the will and the muscles may be obstructed. This obstruction may occur (*a*) in the brain, as in cases of so-called apoplexy from hæmorrhage or embolism, or in cases of chronic degenerative change. (*b*) From acute or chronic change in the spinal cord, causing destruction of the proper nervous tissue of the cord. (*c*) The healthy spinal cord may be subjected to pressure from without, owing to tumour, thickening of the membranes, the fracture of a vertebra, or other similar cause. (*d*) The trunks or branches of any of the cranial or spinal nerves may become obstructed by intrinsic or extrinsic disease in any part of their course from the point where they branch off from the brain or spinal cord to the termination of the nerve-filaments on the fibres of the muscle.

4. Changes causing paralysis may occur in the muscles themselves. The changes seem to be mainly brought about

either by cold, 'rheumatism' (whatever that may be), or overwork.

In those cases where the peripheral terminations of the nerves are no longer in communication with their nerve-centres, or communicate with an effete part of a nerve-centre (a part, that is, whose tissues have been the seat of destructive changes), we get what has been called *peripheral paralysis.*

When the paralysed nerves are still *in communication* with a healthy portion of the nerve-centres, the cause of the paralysis being situated at a point in the cerebro-spinal axis higher than that at which the paralysed nerves join it, then we get what has been called *central paralysis.*

If a part of one corpus striatum be destroyed we get hemiplegia ; and, since the greater part of the brain and the whole of the spinal cord remain unchanged and functionally healthy the paralysis is a central paralysis.

If the spinal cord be compressed by a fractured vertebra we get paralysis of all nerves given off below the fracture ; but, since the part of the spinal cord below the fracture remains functionally healthy, the paralysis is not a case of peripheral paralysis, but must be called 'central.' The spinal cord, it must be remembered, is not a mere passive conductor for nerve-force. It exercises important functions of its own, and it would seem that nerves remain healthy provided that, and just so long as (*cœteris paribus*), they communicate with a *healthy part* of the spinal cord. If the proper spinal influence, which exerts itself independently of all cerebral influence, can no longer exert its power, degenerative changes quickly ensue in the nerves emanating from the damaged portion of the cord.

If the trunk of a nerve be compressed, or cut, or degenerated, or if it communicate with a degenerated portion of a nerve-centre, be it spinal cord or brain, then we get a true case of peripheral paralysis, or, to use the words of Marshall Hall, a case of spinal paralysis.

When a nerve-trunk is cut across, the degenerative and regenerative changes which ensue in the two cut ends are markedly different. In Demarquay's work, 'De la Régénération des Organes et des Tissus,' will be found an interesting summary of the pathology of nervous regeneration. Of the cut ends, that which is in connexion with the nervous centres does not degenerate at all, but degeneration rapidly sets in in the peripheral end, and extends along the nerve. This degeneration of the peripheral end (which seems to consist mainly in the fatty metamorphosis of the medullary substance of the nerve) is completed in about six weeks or two months. The exact condition of the axial cylinders is a matter of doubt, but, according to Erb, of Heidelberg, the degeneration of the medullary substance is accompanied by a thickening of the neurilemma, which, by pressing upon the axial fibre, materially interferes with recovery. In about three weeks after division of a nerve, the muscles supplied by it begin to waste.

When motor nerves and muscles are thus cut off from central influence, and when degeneration has progressed in the peripheral end of the nerve, certain changes are observed in the electric irritability of the nerves and muscles. It sometimes happens that for a few days after the occurrence of the peripheral paralysis, the irritability of the nerve is somewhat increased both to faradism and galvanism.

Soon, however, a gradual decrease of the irritability (of the nerve) to both kinds of current sets in, and (if the cause of the paralysis continue long enough) it ultimately vanishes altogether.

No muscular contraction can then be elicited by exciting the *nerve* with either kind of current, no matter how intense. Irritability once lost is very slow to return, and it is curious enough that the recovering nerve sometimes allows the passage of the mental stimulus at a time when it cannot yet be excited by the electrical stimulus. This is due, according to Erb, to the thickening of the neurilemma, rendering the passage of the electrical current difficult; but, the axial fibres being undamaged, the mental stimulus is able to travel without difficulty. It is asserted that, if the electrical stimulus is applied at a point nearer the centre than the injury causing the paralysis, the excitability of the nerve for this stimulus can be proved.

The changes in the irritability of the *muscle* (in cases of peripheral paralysis) are very different. In the early days of the paralysis the irritability is normal, and then may follow a period during which the irritability of the muscle to both kinds of stimulus may sink somewhat. Between the seventh and fourteenth days after the onset of the paralysis it is found that the irritability of the muscle to faradism is much lowered, and in a few weeks may be completely lost. The irritability to galvanism remains, however, as marked as ever; and as the faradic irritability gets gradually less, the galvanic irritability goes on increasing, and not only increases, but becomes altered in other ways (it is said). Thus the faradic irritability undergoes a mere quantitative change (a diminution). The galvanic irritability undergoes a quantitative and also a qualitative change. As to quantity, the irritability is increased; and you will find that a current of a certain intensity will produce muscular contractions in the muscle which is the seat of peripheral paralysis, while a current of twice the intensity is required to produce a similar contraction in the corresponding healthy muscle. The contraction is of a different character too, and is, so to speak, more lazy and prolonged on the diseased side than on the healthy side.

It is said also, by Brenner and by Erb, that the anodal closure contraction (A. C. C.) soon becomes very marked, and equals or even surpasses the cathodal closure contraction (C. C. C.); and, further, that the cathodal opening contraction (C. O. C.) becomes more marked than the anodal opening contraction (A. O. C.)

This heightening of the galvanic irritability lasts some time, and then a diminution sets in, and the irritability gradually disappears, the last reaction to be lost being the anodal closure contraction (A. C. C.)

These changed muscles react more readily if the interruptions of the current are slow. No reaction is got with momentary currents, faradic or galvanic, and with the galvanic current only if the interruptions are slow. This seems to indicate that the reactions to rapid currents are due to the irritation of the intra-muscular nerves, and when these intramuscular nerves have degenerated then the muscle no longer reacts to rapid interruptions.

With regard to the qualitative changes which we have enumerated, the author may state that he has seen a few cases of peripheral paralysis in which the anodal closure contraction was certainly more readily obtained than the cathodal closure contraction. Of the other alleged quantitative changes he has no knowledge. But since they come to us backed by the highest authority, he would be wanting in his duty did he not lay these alleged facts before the reader.

With regard to paralysed nerves and muscles which retain uninterrupted connection with their nerve-centres, it is certainly surprising for how long a time they remain undiminished in size and irritability. It is a common observation that after a hemiplegia which has endured for many months the wasting of the muscles is often trifling in the extreme, and as often as not the electric irritability to both forms of current remains exactly the same as on the healthy side. If, however, a man injures a peripheral nerve—say his ulnar, or one of the branches of the external popliteal—it is astonishing with what rapidity the muscles supplied by the injured nerve waste, and how soon the electric irritability becomes altered in the manner we have indicated.

Onimus ('Practitioner,' June 1875), in a paper '*On the differences of action of induced and continuous constant currents on the muscular system, from a clinical point of view*,' points out that (*a*) under normal conditions induced currents produce stronger and more definite contractions than continuous currents, but that in certain diseased states, of which facial palsy from cold may be taken as the type, the reverse holds good, and occasionally when the strongest induced currents fail to evoke any contraction, the contractions with galvanic currents are more marked in the paralysed than the healthy muscles. This increased galvano-muscular contraction (as seen in facial palsy) is of a slower character than the farado-muscular contraction of health; its increase is only for a limited time, after which it decreases, and it is now and then observed that the anode has more power than the cathode to produce contraction. As the paralysis disappears the irritability of the muscles slowly becomes normal again. Onimus goes on to observe that these phenomena are only seen in a certain number of cases of peripheral paralysis, and that in most cases of disease or injury of nerve the irritability to both forms of current is diminished. ‘ What,’ he asks, ‘ is the explanation of the fact that in certain cases of peripheral paralysis there is loss of contractility for both kinds of currents; whilst in others induced currents are incapable of exciting contraction, though the excitability is increased for continuous currents ? ’

He adopts the opinion of Schiff that induced currents, unlike galvanic currents, are incapable of inducing idio-muscular contraction, but do so only through the medium of the motor nerves. When, therefore, after injury, the nerves only have undergone degenerative changes, ‘ every excitant which only acts indirectly on the contractility through the intermediation of the nerve fibres will lose its action, whilst that which acts directly on the muscular fibre will preserve its action and remain capable of exciting contraction. When, on the contrary, the nerve lesion is followed by changes both in the nerves and in the muscular fibres, the phenomena of contractility can no longer be called forth either by direct or by indirect excitants.’ Now the cases in which these alterations of contractility are best observed are injuries to ‘ almost exclusively motor nerves, such as the facial, the radial (musculo-spinal), and the peroneal,' and in cases of facial palsy from cold, in which it may be supposed that the intra-muscular terminations of the nerves are early affected, these changes are best marked and appear earliest, because although the whole of the nerve is damaged, the muscles remain healthy. In cases of injury or compression of a nerve trunk at a distance from the muscle, a considerable time elapses before the degenerative changes travel to the nerve terminations, and the characteristic reactions appear. When it appears that degeneration of nerve and muscle coincide, the irritability to both forms of current is diminished. Onimus therefore concludes that 'in order that the farado-muscular contractility may be abolished, and that the galvano-muscular contractility may be augmented, the two following conditions must co-exist:—

I. Alteration of the intra-muscular nerve fibres.

II. Absence of any material alteration of the muscular fibres.'

Let us now apply these rules to actual practice, and take two cases presenting the phenomena of facial palsy. Let us for a while disregard all other symptoms and examine the muscles of the face electrically. In the one patient we may find that the muscles on both sides of the face react equally well both to direct and indirect stimulation, whether faradic or galvanic. In the other case we may find that, whereas the healthy muscles react readily to a faradic current of small intensity, the paralysed muscles cannot be made to contract either to direct or indirect stimulation, notwithstanding that we employ a very intense current; with the galvanic current applied to the motor points of the paralysed nerves we get no result; but when applied directly to the paralysed muscles we find that they react to a current of an intensity too low to produce any result on the healthy side. The inference that we draw from this examination is that, in the first case, we are dealing with a *central*, and in the second case with a *peripheral*, cause of paralysis. This fact, in the first case, would probably be made tolerably clear by the circumstance that the facial paralysis is only part of a hemiplegia. In the second case, too, the peculiarity of the reaction probably only confirms a diagnosis which we might have arrived at by a consideration of the other circumstances. The diagnosis is, however, not always so clear, and then the electrical reaction becomes of great importance. Not long since two cases came under the author's notice which presented apparently the same physical conditions. In both there was wasting and deformity of the right hand. In both the cleft between the finger and thumb was markedly wasted; in both the metacarpal bones stood out in bold relief, owing to the wasting of the interossei; in both there was some 'clawing' of the fingers, owing to the extension of the first and the flexion of the second phalanges. The condition of the hands was, in fact, almost exactly similar. The electric irritability, however, was markedly different. In the one, faradic irritability was much diminished and galvanic irritability considerably increased; it was, in fact, a case of paralysis of the ulnar nerve from injury. The prognosis was favourable, and events justified the prognosis. In the other case faradic irritability was perfect, notwithstanding the wasting of the muscles. It was a case of 'progressive muscular atrophy.' The prognosis was bad; and here, too, events have justified the prognosis, for the patient has got worse instead of better, and other muscles of his body have been attacked in the same way as those of the hand.

These altered reactions, found in muscles in cases of peripheral paralysis, and which Erb proposes to call 'degenerative reactions,' are found in—1. Some forms of *paraplegia* due to destructive changes in the cord. 2. Some forms of *infantile paralysis*. 3. *Traumatic paralysis* due to injury to the nerve-trunks. 4. *Rheumatic paralyses*—i.e. paralyses due to 'rheumatic' thickenings of the neurilemma. 5. *Peripheral paralyses* due to other causes. 6. Paralyses due to *lead-poisoning*.

Dr. Buzzard, in his work on 'Clinical Aspects of Syphilitic Nervous Affections' (1874), speaking (p. 39) of the uses of electricity in the diagnosis of such cases, says—'I have some reason to think that where hemiplegia is caused by thickening of the cerebral membranes, the electrical condition will be found to resemble that which is observed in peripheral paralysis—farado-contractility will be abolished. At present, however, I am unable to speak positively upon this point, which is well worthy of investigation, for if this should prove to be the case it would furnish an important means of diagnosing between softening of the brain substance (a permanent injury) and a temporary interruption of nerve force owing to a compression, which treatment might with confidence be expected to remove.'

It not unfrequently happens that in cases of true central paralysis there are quantitative changes in the electric irritability. In the early days of a hemiplegia following cerebral hæmorrhage, and while active changes may be presumed to be going on in the brain, it is not unusual to find some heightening of the irritability of the nerves and muscles to both currents. Occasionally, too, where the hemiplegia is of long standing and the muscles have been long disused, the electric irritability is in some degree diminished, but as a rule the reader will find the assertion holds good that in cases of central paralysis there is no marked change in the irritability either of the nerves or the muscles. This rule of course holds good with 'central' paraplegia as with 'central' hemiplegia.

In cases of rheumatic paralysis it is not unusual to find the irritability of the nerves heightened in the earliest stages of the disease, and this exaltation of irritability is particularly marked in nerves which are the seat of mild inflammatory action, before, of course, the changes have advanced to destruction of the proper nervous tissue.

It must not be forgotten that in many cases of hysterical paralysis there is not only very considerable wasting of the muscles, but that this wasting is accompanied by great diminution of their irritability. The irritability of the sensory nerves is in these cases diminished also. The diminution in muscular irritability is merely quantitative, and is equally marked to both forms of current. The ‘ degenerative reactions ’ of Erb are not observed. This fact, that in cases of paralysis which are of purely emotional origin, and which are unaccompanied by any organic change, we should meet with wasting and loss of irritability, while in old hemiplegia due to hæmorrhage or similar causes muscles, though powerless, retain their bulk and irritability intact for years, is not a little remarkable, and offers much food for reflection. One great cause of wasting and loss of irritability in a muscle seems to be its removal, not only from *direct mental stimulation*, the loss of which produces these effects in a comparatively small degree as we see in hemiplegia, but, which seems to be of more importance, its removal from *reflex stimulation*, as is the case in all forms of peripheral paralysis, whether due to lesions of the nerve-trunks or the cord itself. It is at least possible that every impression which is made upon us by our environment, no matter whether such impression be physical or psychical, serves to keep up, by a process of constant reflex stimulation, the nutrition of our muscles, and at least it is certain that, when the possibility of such reflex stimulation is withdrawn, the muscles waste rapidly. Now in ‘ hysterial paralyses ’ we not only get a suspension of the power of mental stimulation, more absolute almost than occurs in any other form of paralysis, but the patient loses all interest in the muscles, does not care whether they move or not, and, unlike the victim of hemiplegia, is never to be found rubbing the palsied limbs or making strong efforts to exercise them. With the loss of motor power there is also loss of sensory power, and in these hysterical cases we find the sensorial functions occasionally so deranged that the strongest induction currents and even hot irons applied to the skin fail to produce any evidence of sensation. It is highly probable, therefore, that the nutrition of the muscles in these cases is little likely to be sustained by the reflection of cutaneous impressions, and to this cause possibly may be referred the wasting and loss of irritability which is so often observed.

Electricity is of use in detecting *malingerers.* Occasionally the mere pain of the application will serve to unmask an impostor, but in this respect electricity is no better than any other painful process. We must be careful, too, to remember that in many genuine paralyses there is no impairment of irritability, and we must not rush to the conclusion that, because the muscles are in their normal condition in this respect, therefore there is no true paralysing lesion. To reason in this way would (as a reference to what we have been saying will show) be a grievous error. When, however, we are in doubt as to the genuine quality of any paralysis, if we find the muscles diminished in irritability, and especially if we find them give the degenerative reactions, we need be no longer in doubt, as it is utterly beyond the power of any man to simulate such a condition. The application of electricity has often served to prove the genuine quality of those paralyses which supervene after concussion of the spine in railway collisions, and concerning the nature of which doctors seem ‘ agreed to differ.’

In a lecture, published in the ‘ Lancet ’ for August 22, 1874, ‘ on a case of progressive locomotor ataxy with anomalous joint affection,’ Dr. Buzzard points out another of the diagnostic uses of electricity. The patient, the subject of his lecture, had great swelling of the right thigh, and mere inspection and palpation were not sufficient of themselves to determine whether the enlargement was due to œdema superficial to the muscles or to fluid beneath them. When the rheophores carrying an induced current were placed upon the quadriceps extensor muscle just above the patella (where the swelling was greatest) there was ‘ immediate and powerful muscular contraction, the electric excitability at this spot being, indeed, much more marked than in the corresponding part of the left thigh. The fluid, therefore, lay under and not superficial to the muscle, as would be the case in œdema.’ Lower down, the leg was certainly œdematous ; and there, the conduction of the current being interrupted by the presence of fluid in the subcutaneous connective tissue, the muscles failed to act to the electric stimulus. The increased excitability of the quadriceps extensor in the affected limb was doubtless owing 'to the thinning and tension of the strained skin favouring conduction to the muscular tissue immediately beneath it.'

The third volume of the West Riding Lunatic Asylum Reports (1873) contains a paper by Mr. John Lowe, M.B., on the irritability of the muscles in certain mental and nervous diseases. The experiments were made with a Stöhrer's faradising battery, the absolute strength of current required to cause contraction being recorded in each case; and the chief results obtained were as follows:—

1. The electro-muscular contractility varies in different individuals in ordinary health.

2. That different portions of the same muscle may vary as regards electro-contractility.

3. That variations occur in the electro-contractility of the same individual at different times.

As regards the condition of the muscles in diseased individuals, the results were chiefly negative, excepting that 'in cases of general paralysis, chronic disorganisation of the brain, and locomotor ataxy, in which the power of locomotion was affected to such an extent as to prevent the patient walking without assistance, the electro-contractility of the muscles of the legs was impaired or altogether gone.'

The irritability of the muscles to galvanism was not investigated.

Electricity has been employed for the detection of bullets in wounds, and the following description of the electric probe and the method of using it, is taken verbatim from a lecture by Professor Longmore, of Netley ('Brit. Med. Jour.' Dec. 30, 1871).

'The improvements which have taken place in the modern applications of electricity have paved the way for more simple and yet more sensitive bullet explorers. One of these is the invention of Mr. De Wilde, a civil engineer, and is very compactly arranged in a box of small dimensions. The electric action is excited in a suitable cell; the electricity there developed is increased in intensity by the intervention of a multiplying coil; an exploring probe is connected by insulated wires with the apparatus; and the indication, when the circuit is completed by contact of the two points of the probe with a leaden bullet or piece of iron, is given by the striking of a hammer against an alarum-bell. The bell sounds at each interruption and renewal of contact of the points with metal. The exploring probe consists of a long slender tube of smooth vulcanite, containing two insulated needles, the points of which can be withdrawn within the tube, or be made to protrude, at the pleasure of the operator. Altogether it is an effective appliance as an exploring instrument, owing to the strength of the electric current developed, and the marked manner in which the indications are given by the sound of the bell when a bullet or other metallic substance is met with. There is also attached to the instrument a bullet extractor, the two arms of which are insulated, and so arranged that, when they are connected, in the same way as the explorer, with the battery, they indicate the grasping of the foreign body similarly by the sound of the bell. Unless the metal be firmly grasped by both blades, without any other substance intervening, the indication will not of course be given.'

'Another instrument of a similar nature has been made by Messrs. Krohne and Sesemann, of London. The indications of contact with a lodged bullet or other metal are in this instrument afforded by the movements of a galvanometer, and of a fine needle working upon a dial-plate, in the same manner as is seen in the ordinary single-needle telegraph. I have experimented with both these instruments, and have found them equally effective in their indications. Attached to the latter instrument is not only a bullet-extractor as well as the explorer, but also a pair of acupuncture needles, for use in cases where metallic bodies are supposed to be lodged in soft tissues, away from any means of approach by a wound or sinus.'

'A rough but sufficiently effective electric instrument for facilitating the discovery of metallic substances lodged in gun-shot-wounds has been made in the following way. The magnet of an ordinary pocket-compass, which has had some turns of wire covered with thread wound round it as an induction coil, is employed for the electric indicator, while a piece of copper sheeting, bent round a small plate of zinc, but separated from it by flannel padding saturated with the usual diluted acid, forms the voltaic pile. The exploring instrument is formed by two insulated wires, bound together, but with the points left free. These parts being connected, when the circuit is completed by contact with metal, the indication is given by movement of the magnet of the compass.'

Lastly, electricity has been used to diagnose death, and in doubtful cases may be of service. The muscles remain irritable for periods of two hours and less after death has taken place; and the process to which the high-sounding title of *Electro-Bioscopy* has been given consists in testing the muscles with faradism to ascertain whether or no they can be made to contract.

M. Onimus has made experiments on the bodies of criminals after execution, and he has shown that galvano-muscular irritability persists for some time after farado-muscular irritability. The first muscles to lose their irritability are the diaphragm and the tongue, and then the muscles of the face. The irritability of the extensors of the limbs is lost at least an hour before that of the flexors.

CHAPTER VI.

ELECTRICITY AS A STIMULANT.

It will perhaps be as well, on commencing the subject of Electro-therapeutics, to call to the recollection of the reader some remarks made by Dr. Reynolds, in his 'Address on Medicine,' delivered before the British Medical Association at Norwich, in 1874. Dr. Reynolds' remarks are as true as they are thoughtful, and a perusal of them may serve to check any mischievous excess of zeal which may be felt by a new worker in the field of electro-therapeutics. Dr. Reynolds, in addition to much besides, said—'The obvious "correlation" of the physical and vital forces has led some to believe not only in the correlation of forces and actions, physical and vital, but, further, in the identical nature of the two; and so, that which constitutes the true differentia of life, appears to me to have been lost sight of in the very brightness of the light which has been thrown upon the conditions of its action. . . . Physical force may be correlated to vital acts, but life itself is the special property or condition of the special material which effects that peculiar relation, and it is as far from comprehension now as it was a thousand years ago. . . . If we apply electricity to a nerve trunk, a cerebral convolution, or a more central structure of the brain, motions of definite character, association, and sequence may result; but the secret of life still lies hidden in the properties of those nervous elements which transmute such electrical impressions into the facts of muscular contraction and association of muscular contractions in the movements of the limbs.' Dr. Reynolds fancies 'that many are disposed to think that, if we could make our experiments a little more clever, that if we could carry our machinery of experimentation but a little farther—and there is no doubt that we shall do so very shortly—we shall get rid of the term and the idea of life itself, and so make a great advance in science. It may be that this will be done, but for one I believe that it will not be done, but that there will ever remain the same kind of mystery with regard to life itself—however keenly and satisfactorily many of its processes may be referred to simpler agencies—that still shrouds the nature of those simpler forces, such, for instance, as gravitation or heat, with regard to the nature of which we have ceased to question. . . . The view that is taken of the correlation of vital and physical forces, when it assumes the form that I have mentioned, is, I think, mischievous in therapeutics. That which is the differentia of life is, as it seems to me, lying in the organism, and is that which makes it capable of transforming physical forces into vital acts. But what we are often attempting to do in our treatment of disease is to elicit vital action rather than to conserve vital force. . . . In the present day, electricity, in its many forms, has come again into fashion, and constant and faradic currents, chain batteries and magnetic belts, are topics of common conversation and articles of dress in boudoirs and clubs, as well as in the consulting-room of the physician. The mischief that is being done by such abuses of a very valuable therapeutic agent is grave and manifold; but is the profession altogether blameless in this matter? There are some conditions in which electricity is very useful, and useful by calling into play the function of nerve and muscle; but it has again and again been used when it could by no possibility have been productive of the slightest advantage, and when the production of such enforced action of muscle and nerve has but diminished the strength and exhausted both the energies and the endurance of those who had not one grain of either of those qualities to spare. Muscles and nerves have been driven into action when they needed rest; but that which has guided the practitioner into such mistaken practice has been the notion that to evolve function was the great end of treatment, whereas, what was really needed was a conservation of the central nutrition, and a consequent addition to the stock of vital force. Rest, food, cod-liver oil, and soothing drugs were needed, and not faradisation, alcohol, or strychnia.'

It will be well for the practitioner to make himself thoroughly acquainted with the fact that a muscle may be completely tired out by the injudicious use of electricity, and if he will take the trouble to make the experiment on one of his own healthy muscles, he will learn a lesson which will prove of great advantage to his patients.

Select a small muscle (and it is well to select one which is not very frequently called into voluntary use for ordinary purposes), such, for example, as the first dorsal interosseous muscle of the left hand. Faradise it, using a current of sufficient strength to cause a contraction which is too forcible to be overcome by the will, and it will be found that, after three or four minutes, the contraction becomes less and less strong as the irritability diminishes, and that the will is soon able to overcome the artificial contraction, while the same current, applied to the corresponding muscle on the opposite hand, causes a contraction against which the will is absolutely powerless. Ultimately, the faradised muscle will refuse to respond either to mental stimulation or to faradism.

The heart appears to be very susceptible to anything which upsets the rhythm of its nutrition, and after a spasmodic contraction caused by faradisation, it seems unable to recover itself, and complete cessation of action has resulted.

M. Vulpian found that, when a strong faradic current was applied to the heart of a dog, rhythmic contraction at once ceased, violent tremor of the cardiac walls occurred for three or four minutes, followed by slighter trembling for the same space of time, and then all movement ceased. The muscular substance became pale. When all movement, even fibrillary, had ceased in the ventricles, their walls seemed to have lost, almost entirely, their contractility. When touched again with the rheophores there was not the slightest contraction, nor did stimulation, by rhythmical compression by the hand, reproduce their movement. These effects were not altered by section of the pneumogastrics, nor by the subcutaneous injection of atropine which paralyses the cardiac extremities of the moderator fibres of the pneumogastrics, which shows that the result is probably due to exhaustion of muscular irritability rather than to the specific action of any nerve.

It may be said, then, of electricity, as of all other stimulants, that, while the judicious employment of it is often of the greatest service, its abuse is often fraught with mischief and with danger. The chief use of electricity has been in the treatment of paralysis, and for this end it has been used in all its forms—static, faradic, and galvanic. In a volume of essays published by Dr. Percival, of Bath, in 1773, will be found the records of 'a case of a palsy, arising from the effluvia of lead, in which electricity was successfully employed.' The case was that of a man aged twenty, who had worked in a lead mine, and who became so extensively paralysed that, in September, 1768, when treatment was commenced, 'the head was the only part he could move.' His paralysis resisting all the usual remedies which were then in vogue, he was submitted to a series of shocks sent through his limbs from a Leyden jar, and, after eighteen months of persevering treatment, he was discharged, perfectly cured. From this essay one gathers that even then the utility of electricity was hotly debated, and many untoward accidents had happened from the employment of Leyden jars of large size. Dr. Percival cautions his readers against giving electricity in 'dangerous doses,' and says that the largest shock he had ever found of use was that from an 'eight-ounce phial coated in the ordinary way.'

In Dr. Reynolds' lectures on the 'Clinical uses of Electricity,' the perusal of which the author cannot too strongly recommend, the reader will find exact rules for the treatment of the various forms of paralysis.

First, as regards *Cerebral Paralysis*, arising suddenly from one of its common causes, such as hæmorrhage or embolism, and in which the paralysis takes the usual form of hemiplegia. The question is, What will electricity do for the patient? In the early stage of these cases, Dr. Reynolds says, 'it is very unwise to disturb the patient in any way; the best thing for him is to be let alone; so pray do not use electricity.'

Dr. Bastian, too, in his work, 'Paralysis from Brain Disease,' expresses the same opinion, and says, 'Do not, in the early stage of hemiplegia, resort to electricity. Harm may be done by a too early faradisation of muscles, and, as for galvanisation of the brain, i.e. the passage of a galvanic current through the head, I would not counsel you to have recourse to it at any stage. An early adoption of such a method might do actual harm, and when it is had recourse to later, it is, to say the least, not likely to do any good. I am not aware of any sound principles upon which such hap-hazard attempts at amelioration could be recommended.'

That the opinion of the generality of physicians coincides with that of Dr. Reynolds and Dr. Bastian there can be no doubt, but the question has been largely debated, especially in Germany, as to whether or no the cure of the paralysing lesion can or cannot be hastened by applying galvanic currents to the cervical, sympathetic, or to the cerebral hemispheres themselves. Some cases of transient hemiplegia have been supposed to be due to a spasmodic contraction of the cranial bloodvessels, and it is at least possible that this condition may have been present in those cases in which galvanisation of the brain is said to have resulted in immediate benefit to the patient. That the application of galvanism to a limb quickens the nutritive processes in such limb there can be no doubt; and all physicians who have employed electricity are agreed on this point, but few would be inclined to argue from this that the application of currents to the head or neck is capable of hastening the absorption of a clot, or of checking degenerative changes in the vessels of the brain. The question is one which can be decided only by clinical observation, and it is to be hoped that such observation may be forthcoming, for it is tolerably certain that the application of a mild continuous current to the head, if it be applied with ordinary care, is not likely to do any harm, even if no decided benefit result. It would, however, be advisable to allow at least a week to elapse before using such methods. It is urged, on behalf of early galvanisation of the brain, that, not only is absorption hastened, but that degenerative changes, which may result from the primary lesion, are prevented and held in check.

It is never advisable to employ faradism in cases of cerebral paralysis, as long as the patient presents any head symptoms, pain, weight, giddiness, or delirium, nor if there be that condition of the muscles known as early rigidity. From the injudicious use of electricity in these cases, disastrous consequences have, before now, resulted. After the paralysis has lasted some time, and there is fear of the muscles degenerating from disuse, 'our aim must be,' says Sir Thomas Watson, 'to preserve the muscular part of the locomotive apparatus in a state of health and readiness, until, peradventure, that portion of the brain from which volition proceeds, having recovered its functions, or the road by which its messages travel having been repaired, the influence of the will shall again reach and reanimate the palsied limbs.' It occasionally happens that the first few applications of electricity are followed by the almost immediate improvement, to a certain extent, of motor power. It would almost seem in these cases as if the application had had the effect of calling dormant tracts of nerve tissue into activity, and of forcing new channels for the mental stimulus. This rapid improvement soon ceases, and further faradisation does but little good.

If the paralysis of the will remain absolute, and if the contractility of the muscles be perfect, we do no good by persevering with faradisation; for, if the contractility be perfect, there is no indication for faradisation. If the contractility of the muscles be lowered, faradisation is useful, in so far as it helps to improve their nutrition and restore their healthy degree of contractility. This point being reached, its employment may be discontinued. If there are signs of faulty nutrition of the limb, wasting of muscles, blueness of the skin, and chilliness, then electricity, in both its forms, is of service. All the muscles should be faradised by turns for a few seconds, taking care not to neglect the intrinsic muscles of the hands and feet. The galvanic current may be used, too, with advantage. The positive pole may be placed on any indifferent part of the body, and the paralysed limbs may be thoroughly sponged with the negative pole, previously moistened with hot salt and water. This should be continued till redness of the skin is produced, but should not be prolonged over three or four minutes. After the galvanic sponging, the limbs should be thoroughly rubbed with a soft towel. In this way the nutrition of the individual muscles and the other tissues of the limb will be sustained. The return of voluntary power depends upon the extent and nature of the central lesion, and if, notwithstanding a favourable condition of the limb, the paralysis to the will remains absolute, there is no good in continuing the electrical treatment. In using faradism, always employ the weakest currents which will bring about the required contraction, care being taken never to cause the patient unnecessary pain, and always to test the strength of current on one's own body before applying it to others.

In cases of late rigidity, we may often do much good by faradising the extensor muscles of the fore-arm, and by galvanising the rigid muscles. We sometimes meet with old neglected cases of hemiplegia, in which the flexor muscles have been allowed to contract, and we can in such cases (especially if the patients be young) often do a large amount of good by a persevering and intelligent use of electricity. Accessory measures for causing the stretching of the contracted tendons, such as the elastic extension of the fingers, &c., will be found greatly to assist a cure. Especially, too, in such cases, as, indeed, in all cases of paralysis, it is important to make the patient diligently practise all the voluntary power he is capable of exerting. As much good is often done by rousing in the patient's mind an intelligent and hopeful interest in his condition, as by the employment of other therapeutic means. It will be found, too, in the treatment of chronic cases of paralysis, that a great deal is often to be done by ingenuity and dogged perseverance. When we read in Duchenne's work of the great success which in some instances crowned his prolonged treatment of old abandoned cases, one cannot help thinking that as much was owing to the wonderful perseverance of the physician as to the therapeutic measures he adopted. We cannot too strongly recommend the perusal of Duchenne's work on Localised Electrisation. The clinical division of it will be found a veritable mine of observation, ingenuity, originality, and research, although the author, perhaps, is too prone to recommend the employment of faradism to the exclusion of all other forms of electricity.

Of the three methods of treating hemiplegia electrically (by direct galvanisation of the encephalon, by galvanising the cervical sympathetic, and by localised faradisation), Dr. Clifford Allbutt declares that the first two are almost unworthy of consideration ('British Medical Journal,' September 2, 1871):—'Galvanism applied directly to the encephalon is very injurious so long as any active change is going on within it; but when the disordered parts have recovered their stability, such applications seem to be of value in restoring the normal molecular activity. This is analogous to its action in cases of overwrought or depressed brain, when very gentle direct applications of galvanism are useful, together with rest, good nourishment, and other remedies. . . . Hemiplegia, more than any other palsy due to organic disease, is susceptible of relief under strong mental impressions of any kind. This source of error must, therefore, be especially guarded against.'

With regard to galvanisation of the sympathetic, Dr. Allbutt says :—'It is far from unlikely that the effects attributed to it are due to reflex action, and may be called forth by any strong impression upon the cutaneous nerves of the region. We have much physiological evidence of such modes of action, and we have clinical evidence also in such cases as to the effect of cold douches or blistering the nape, in dissipating coma.' Dr. Allbutt considers that the effect of galvanising the neck is the same as that produced by blistering.

Although Dr. Allbutt gives in his entire adherence to localised faradisation as a means of treating hemiplegia (and our practical experience, apart from all theory, would lead us to agree with him), it is to be observed that he does not deny that galvanism of the encephalon or cervical sympathetic may produce effects; and we must be allowed to point out that it is no argument against these methods (however unworthy of confidence clinical experience may or may not prove them to be) to say that they merely resemble 'mental impressions' or 'counter-irritation.' Electricity, the emotions, and cantharides are all capable of stimulating tissues, and the clinical physician must make his choice of remedies.

In treating cases of *paraplegia* the same indications will hold good as with hemiplegia. No kind of electrical treatment is admissible so long as there is any sign of active change in the cord. If the cord itself be much damaged we may find that some of the paralysed muscles give the degenerative reactions, and then it is advisable to use the galvanic current in preference to the faradic.

We may often also by employing faradism relieve those symptoms which are such a trouble to paraplegic patients and which are referable to the bladder and rectum. The following case is a good illustration of the use of electricity in paraplegic conditions.

Case I.

Paraplegia from Injury.—Mr. G. T., a married man, æt. 37, while in India, at the latter part of 1873, was thrown from his horse, and alighted forcibly on his buttocks and back. Paraplegic symptoms supervened, and failing to get much better he came to England to seek further advice. He was first seen by the author on May 14, 1874. At that time there was considerable loss of power, though no absolute paralysis, in both legs, but especially the left. There was slight bulging of the dorsal region of the back, but no sign of caries. The general health tolerably good, but he was much troubled by pain, like sciatica, affecting the left leg; by obstinate constipation of the bowels, which acted only at intervals of three or four days; and by an incessant dribbling of urine which necessitated his wearing an indiarubber urinal. On examination it was found that the abdomen was distended, and that the urine had a most offensive ammoniacal odour. There was no sign of distension of the bladder, and the distension of the abdomen was caused apparently by a flaccid condition of the recti abdominalis muscles. In conjunction with Mr. Marcus Beck, it was first ascertained that no organic change was present in the bladder or urethra; and the bladder was washed out with a solution of quinine which (being repeated once or twice) completely removed the offensive condition of the urine.

His constipation being apparently due to the want of power in his recti-muscles, these were faradised, and in a very few days the bowels began to act regularly, and he found himself able to have his trousers and waistcoat, which had been previously enlarged to meet the increased girth of his abdomen, 'taken in.' The region of the bladder and the weakened legs were also faradised twice a week, and in a month he went into the country relieved of his constipation, his dribbling, and his sciatica, and with very greatly increased power in the legs.

The above is a good instance of the favourable changes which a judicious use of electricity will occasionally effect. In those patients, too, in whom there is incontinence of fæces the application of electricity to the rectum will sometimes serve to recall a sufficient amount of power in the sphincter to remove this trouble, even though they show no sign of further improvement.

In those most troublesome paralytic conditions known as '*locomotor ataxy*,' electricity must be most cautiously used. In these cases the spinal cord is the seat of degenerative changes, which usually show a tendency to progress steadily, and we ought to feel well assured that the application of electricity will not hasten the degenerative process. There is usually no indication for the use of faradism, since the muscles show no lack of power, and the only question to be determined is whether or no galvanism is likely to be of service. It is asserted by some that the passage of currents across the cervical sympathetic and down the back has served, if not to cure, at least to improve the condition of patients suffering from ataxia. The author has never seen any improvement whatever in the ataxic symptoms from the use of galvanism, but he is fully satisfied as to its great use in alleviating the shooting pains in the limbs with which these patients are so often troubled.

In that most troublesome and tedious of all forms of paralysis, the *Infantile or Essential Paralysis*, the physician will often find his perseverance taxed to the utmost. It is admitted on all hands, however, that electrical treatment is of the greatest service in this disease, and by its means alone we can, not seldom, ward off those distressing deformities which are the too frequent result of this form of paralysis. The children are generally brought for advice too late, and are seldom subjected to electrical treatment until after the disease has lasted some time. Judging from the successful results of electrical treatment in the late stages of the disease when the degeneration of the nerves and muscles is far advanced, it is only reasonable to suppose that, were they subjected to the same treatment in the earlier stages, and before the advance of degenerative changes, the success would be so much the quicker and more marked. When the cases are presented to us we generally find the paralysis strictly localised to one limb, or perhaps only a few muscles of this limb have been picked out by the paralysing lesion—whatever it may be. These muscles are usually greatly wasted, voluntary motor power has quite disappeared, and the irritability of the muscles to both kinds of current may be completely destroyed. These extreme cases give us little reason for hope, and if after a few applications of the galvanic current, locally to the muscles and generally to the limb, we get no improvement, there is little use in continuing the treatment.

If, however, irritability to either form of the current remain in any of the muscles, we have more reason for hope, especially if the faradic irritability still exists, and to a less degree if the galvanic irritability alone remains, and we should sedulously work at the muscles with that form of current to which they most readily respond. We may find that, after a few applications of the galvanic current with slow interruptions, the muscles begin to react to a more rapidly interrupted current, and ultimately we may produce some contractions with a slowly interrupted faradisation. This will show that we have done real good to the case and should encourage us to persevere. The treatment often requires to be exceedingly prolonged, and with intervals of rest has not unfrequently to be renewed again and again. The friends of the child should always be warned as to the probable length of treatment.

The author believes that the general galvanisation of the limb—a spinal-surface current—is of great use in improving the general nutrition, and after its employment it is often found that the limb, which previously was cold and blue, has begun to glow with warmth. The limb should always be kept wrapped in flannel, and frequent rubbings with some bland liniment should be had recourse to.

At the Royal Infirmary for Children and Women the author has had considerable experience in the treatment of cases of infantile or essential palsy, and he has become highly impressed with the utility of galvanism, not so much in restoring the power of individual muscles as in improving the general nutrition of the limb. The following case, which has been taken from the notes of Mr. W. O. Day, the house-surgeon, is a good example of the kind of benefit we may sometimes effect.

CASE II.

‘*Essential*’ *Paralysis.*—Ada Q., æt. 11 years, was admitted to the Royal Infirmary for Women and Children, Waterloo Road, S.E., in December 1874. Her mother stated that in the previous August she had been laid up with an attack of rheumatic fever, and that during the attack it was noticed that the left leg was powerless. The mother further stated that the left hip had been the joint chiefly affected by the ‘rheumatism.’ On examination there was found to be no existing disease of the hip joint, and no sign of heart disease. The left leg was absolutely powerless, the only muscular movement possible being a very slight flexion of the toes. The limb was smaller than its fellow, and was always cold. Locomotion was impossible, since the left leg swung like a flail from the hip, and was absolutely useless either for support or progression. No response of any of the muscles could be obtained to the strongest currents of either faradism or galvanism. She was ordered 2 minims of liquor strychniæ three times a day; the limb was kept constantly covered by a thick woollen stocking, and hot-water bottles, constantly renewed, were placed to the left foot. The limb was further galvanised daily, a current of 10 or 12 Stöhrer cells being used, the positive pole being placed on the lumbar spine, while the whole surface of the limb was sponged with the *negative* rheophore. After each application the limb was thoroughly rubbed with a rough towel, and the effect was to make it red and warm. This treatment was continued with the greatest regularity, but it was not till the beginning of April that any contraction of the muscles followed the application of the current. At this time the gastrocnemius began to respond to the slowly interrupted galvanic current, and this was followed in a short time by a similar return of irritability in the tibialis anticus, and it was noticed that the power of flexing the toes had greatly increased. The treatment was continued and the patient was induced to use the leg as much as possible. She began to get more power in it generally, and to walk about the ward, at first with great difficulty, but with gradually increasing power and ease. To prevent flattening of the sole, she was provided with a 'flexura boot,' *i.e.* a boot having a steel band in the waist; and, to assist the weakened tibialis anticus, an elastic band was carried from the inner side of the sole of the boot to a broad padded garter worn above the knee. On July 1, 1875, she was made an out-patient, being able to walk considerable distances without any trouble. Although the power of the limb is now greatly increased, and its temperature is not so uniformly low, it is not easy to see how walking is effected. The extensor of the thigh does not *appear* to act, but the foot is moved forward by the flexors of the hip, assisted, however, one cannot help suspecting (although it is not evident), by slight power in the extensor femoris. The galvanic contractility of the flexors and extensors of the ankle has much improved, but nevertheless voluntary power exists only in the latter. There is no reaction to faradism. The hamstring muscles and the glutei act tolerably well. Although, when the power of individual muscles is thus analysed, the improvement seems slight, still practically the improvement is very great, for when first she came under treatment the leg was simply a hindrance to her, whereas it is now of very great use, and the improvement which has been started will probably make steady progress, the reparative power in children being so enormously great.

CASE III.

Essential Paralysis ('British Medical Journal,' June 17, 1871).

'Fanny ——, æt. 5, attended at the Leeds Infirmary, under Dr. Clifford Allbutt, during the winter, 1870–71. She was well nourished and of healthy appearance and parentage. She was utterly unable to walk or even to stand. Legs smaller than natural, cold and flabby to the touch. This palsy was not referred to any definite date, but the child never had been able to walk. If the palsy had set in during early childhood, its onset, even if attended by some fever, might nevertheless have been unnoticed. On testing the legs with faradism, there was no motor reaction whatever, but sensibility to the current was preserved, and probably exalted, as the gentlest applications seemed to distress the child extremely. Faradism was applied a few times to see if any reaction was awakened, but without success, and the continuous current was therefore substituted for it. On applying a current of 15 of Muirhead's cells, full contraction of the muscles was readily obtained, and the whole limbs were thrown into strong movement by placing one (positive) pole upon the lumbar spine, and the other upon the legs successively; after about half-a-dozen sittings a slight reaction to faradism began to appear, and the two kinds of electricity were then applied alternately. During this time the child slowly improved; she could walk with the help of the furniture, and astonished her mother one day by coming down stairs. At this stage, however, she became stationary; no further improvement appeared, nor did the muscles recover full susceptibility to the faradic current.'

Apropos of this and similar cases, Dr. Clifford Allbutt remarks, 'Always use very gentle currents to children, whether continuous or interrupted. . . As you patiently work on with gentle applications—say every other day for two or three minutes at a time—you will, if you are fortunate, find that the muscles which were formerly sensitive only to the long currents of the galvanic battery, are now becoming capable of reaction to the short currents of the faradic machine. You must now work the two methods together, giving about two minutes to the continuous current, and two minutes to the interrupted current, alternate days. As the patient improves, the susceptibility of the muscles to galvanism will decrease, and faradism may be used alone. By steady perseverance very remarkable relief may thus be afforded in a few cases, though in too many you will find that, after reaching a certain point, you can get no farther, and the treatment has to be laid aside. . . Together with the electric treatment you will also make use of rubbing, frequently applied to the affected parts, and the limbs should be sponged in hot brine; but you will find that the low temperature is one of the first defects which are removed by the electricity.'

At the meeting of the Medical Society, London, on December 23, 1872, Mr. William Adams brought forward two cases illustrating the advantages of galvanism in infantile paralysis. 'Both legs should be put under water in separate vessels, and then one pole should be applied to each limb. After this each muscle should be separately galvanised.' If recovery did not take place in six months the case was almost hopeless. Mr. Bryant was of opinion that early galvanism was injurious. He had seen bad results from that practice, and thought it should not be used under three or four months. ('B. M. J.,' January 25, 1873.)

Infantile Paralysis and Progressive Muscular Atrophy are both characterised by wasting of the muscles. In the former disease the paralysis precedes the wasting, which follows rapidly; in the latter disease the loss of power proceeds *pari passu* with the wasting. The lesions found in the spinal cord in these two diseases have been very similar. How, then, are we to account for that striking dissimilarity in their symptoms, viz. the rapid abolition of electric contractility of the muscles in infantile paralysis, and its perfect retention as long as a muscular fibre remains to contract, in the latter disease?

M. Vulpian endeavours by a scientific use of his imagination to account for this difference. He says, 'The fever which precedes or often characterises the onset of infantile paralysis might very well be the result of an inflammatory action, beginning in the grey substance of the cord, and producing absolute loss of the functions of that substance in the inflamed parts. This inflammatory irritation would subside in a short time in those regions which were least affected, and would, on the contrary, lead to irreparable lesions in the nerve cells that were most severely affected. At these latter points the nerve fibres which originate from the cells would be deprived, in a few days, of their trophic centres, and would undergo granular and fatty degeneration.'

He supposes that in progressive muscular atrophy the lesion is more chronic, and that 'the nerve fibres in connection with the cells of the altered region retain, more or less completely, and for a shorter or longer time, their normal structure and properties.'

This theory is plausible enough as applied to infantile paralysis, but it seems to us that the explanation offered of the phenomena of progressive muscular atrophy is far from satisfactory.

Dr. Bouchut, of the Hospital for Diseases of Children, in Paris, holds strongly to the opinion that in some cases, at least, of infantile paralysis the fatty degeneration and wasting of the muscle is the primary lesion, and only if this be allowed to go untreated is there a danger of the nerves or cord becoming permanently damaged by 'ascending neuropathy.' He advocates immediate treatment of the paralysed muscles by means of the continuous current, locally applied, and quotes successful cases in support of this treatment and the theory upon which it is founded. ('Bulletin Général de Thérapeutique,' tome lxxxiii., August 15, 1872.)

Progressive Muscular Atrophy is a condition which is probably a symptom of more than one pathological state. It is characterised by great wasting of the muscles, which, however, retain their irritability to the last. We must never forget that the tendency of all forms of this disease is to progress. It may lie dormant, as it were, for a time, but the condition once established is very liable to recur; we must be careful not to over-treat these patients and not to exhaust their muscles by electric currents, for it has been established as a fact that in many of these cases muscles which have been most used waste with the greatest rapidity. The concomitant symptoms of the muscular atrophy are fibrillary tremor and quivering of the muscular tissue and rheumatic pains in the back, joints, and elsewhere. Duchenne has had very good results by employing faradisation in these cases, but it would be necessary to use the greatest caution, while employing it, to act upon the muscles for very short periods of time and with the gentlest currents possible. If the fibrillary tremor of the muscles increases, faradisation should at once be discontinued.

The author believes that galvanism is often of decided service in muscular atrophy, and if it has no power to *cure*, it certainly has power of relieving symptoms, if not of checking the course of the disease. The current should be used more or less continuously, and the patient should be encouraged to gently exercise the damaged muscles voluntarily during its passage. The skin over the muscles should be reddened by the current, and gentle friction may be used as an auxiliary measure. The author has seen Dr. Radcliffe's 'positive charge' of decided benefit, and he has had in one case the advantage of that physician's valuable personal advice. The patient was a lady in whom there was considerable wasting of one hand and shoulder, with marked fibrillary tremor in the deltoid, pectoralis major, trapezius, and sterno-mastoid, as well as some thickening of the finger joints, pain about the shoulder joints, and considerable fatigue and weakness of the back. The negative sponge, to which an earth wire was attached, was applied to the nape of the neck, the patient having been thoroughly insulated. The hands were then placed in a basin of salt and water, and the current was allowed to 'run' for twenty minutes at a time, with occasional interruptions. The legs were treated in the same way, and the back was also thoroughly sponged. The current was from ten to twenty small Leclanché cells. The effect of this over the fibrillary tremor was most marked, as well as over the pains in the back. The patient, moreover, seemed to enjoy the current; it seemed to act as a stimulant, and to give her more power for a time, and this is a very common experience with all who have had much experience with the constant current. It seems to refresh patients, and it is very common to find, both in hospitals and in private, that they are willing to put themselves to considerable trouble for the sake of getting it. One obvious result of Dr. Radcliffe's earth wire is this: that it is possible to leave the negative sponge stationary on the body without running any risk of causing undue irritation.

The origin of progressive muscular atrophy has been referred (and it would be difficult to say what has not been so referred) to the sympathetic, and 'galvanisation of the sympathetic' has been said to give good results. The author has employed 'galvanisation of the sympathetic,' but, with the exception of giving annoyance to the patient, no result was observable.

In cases of *Traumatic and Rheumatic Paralysis*, that form of current should be used to which the muscles most readily respond. Under this head are included those forms of paralysis which are brought about by direct injury to nerves by stabs, cuts or gunshot wounds, and cases in which the nerves have been subjected to prolonged pressure or have been bruised (*e.g.* injury to the ulnar nerve from leaning on the elbow, or to the nerves of the brachial plexus from the use of crutches). Duchenne includes under this heading certain forms of congenital paralysis from injury to nerves occasioned by obstetric manipulations. In the 'rheumatic' cases the nerve is pressed upon by rheumatic thickening of its sheath. This is seen in some cases of facial palsy arising from cold. Facial palsy due to disease of the temporal bone cannot be called traumatic or rheumatic, but it is distinctly analogous to both these forms of paralysis. As in infantile paralysis, the greatest perseverance is needed in the treatment of these cases. The muscles are liable to rapid wasting, and if the treatment be allowed to intermit for too long a time, any improvement which may have been effected is soon lost again. If the muscles make any progress towards recovery, it is found that whereas in the early stages they only reacted to galvanism, in the later stages they begin to react again to faradism. In these cases, and especially if electric treatment be neglected, it is found that notwithstanding the ultimate return of voluntary power, the muscles remain permanently smaller than their fellows on the opposite side of the body. The author has had an opportunity of examining the left hand of a gentleman who six or eight years previously had suffered from paralysis of the left ulnar nerve from pressure. Voluntary power had returned, and the left hand was, for all purposes, as useful as its fellow, but a most cursory glance served to show that the interossei muscles and the adductor of the thumb on the left side were hardly more than half the size of those on the right.

In the treatment of facial palsy we are warned that tonic contraction of some of the facial muscles is liable to occur, thereby causing great deformity of the face. This tonic contraction is preceded by a fibrillary tremor of the muscles, and when this sign is seen faradisation must be discontinued. In these case of tonic contraction Dr. Tibbits states that he has found Dr. Radcliffe's positive charge of great use.

Judging from the report on 'Electricity as a Remedial Agent,' in the 'Guy's Hospital Reports for 1852,' by Sir W. (then Dr.) Gull, the process of 'taking sparks,' was most effectual for the relief of facial palsy. Ten cases are recorded, in all of which this method of treatment seemed to have excellent effects. The following case is of interest as showing, not only the good effects of the treatment pursued, but as furnishing a good example of the course which facial palsy is apt to take, and the trouble which may be caused by the unequal rapidity with which the muscles recover.

Case IV.

Facial Paralysis from a Coup-de-vent.—'W. T., æt. 27, a gentleman of rather weak constitution, was in his usual health until three days before I was called to see him. He was then under some alarm on account of paralysis of the right side of his face. Although he took no notice of the circumstance at the time, he informed me on inquiry, that three evenings before he had stood talking with some friends for a few minutes at the door, whilst the cold air was blowing upon him. The following morning he had pain in the ear and pain and stiffness in the cheek, and the next day it was completely fallen. His health was as usual, and he had no other nervous symptoms. As there was pain about the exit of the seventh nerve, Dr. Lodge, of Peckham, who called me to see the case, applied two leeches with a blister and other appropriate treatment. It only remained for me, therefore, to advise electricity to the cheek. This was first employed on October 20, and it was not before the middle of December that marked signs of improvement followed. On January 31 the following report was taken in the ward-book: 'The angle of the mouth can now be moved with tolerable freedom. The branches of the orbital nerve are still completely paralysed.' The electricity was persevered with, and about the beginning of April our patient was in some dismay, thinking, as he said, that the electricity was doing too much, since the face, instead of being drawn over to the right side, as it had been, had now begun gradually to be drawn too much to the left. The cause of this was obvious. The zygomatic and levator anguli muscles of the paralysed side had recovered more rapidly than their antagonist, the orbicularis oris; and hence the face was on this side now too much drawn up. By directing the stimulus of the electricity to the paralysed half of the orbicularis, its power slowly increased and the deformity lessened, although traces of the want of balance are still obvious when the patient laughs. In other respects the recovery has been nearly complete, the treatment having been persevered with for six months.' (Dr. Gull, 'Guy's Hosp. Rep.' 1852.)

Local Paralyses of other kinds were successfully treated by 'taking sparks,' and Sir W. Gull, in his Report, quotes many such cases in which electricity was frequently the only treatment and produced excellent results. One case of palsy from the use of a crutch is recorded, and eleven cases of paralysis from pressure on the arm during sleep. Of these eleven cases, in nine it was the right arm which was affected, and 'nine of the eleven cases occurred in men,' which was considered as probably due to their habits, 'fatigue and drink rendering them more prone than women to fall to sleep in an uneasy position.'

Case V.

Strains of the Shoulder, causing Weakness of the Arm.—Nov. 20, 1851.—T. B., æt. 55, a corn porter, in February last, whilst lifting a sack of corn, strained the muscles of the right shoulder joint. On the next day he was unable to raise the arm, and had considerable pain in it. For this he first used liniments, but without benefit. In June he was admitted into the hospital under the care of Mr. Hilton. For nine weeks starch bandages were applied, and for five more he wore splints. Neither of these measures gave him any relief, and it is now a fortnight since he discontinued them. He has a weak heart and ossified arteries, the brachial of the right side being very rigid; the veins also are dilated. There is great weakness about the shoulder joint, and the muscles are wasted; he is also unable to close the hand. It was supposed that there had been rupture of the tendon of the biceps, but the head of the humerus is not now in any degree thrown forward. Ordered 'sparks' to be drawn from the shoulder and down the arm. The improvement in this case was remarkable and rapid. On December 27, four weeks after the commencement of the treatment, the report runs thus: 'Much improved; he can close the fingers and raise the humerus above the level of the shoulder.' (Sir W. Gull, 'Guy's Hosp. Rep.' 1852.)

Case VI.

Paralytic Strabismus, cured by Tenotomy and localised Faradisation. (Mr. Brudenell Carter, 'Clin. Soc. Trans.' vol. v.)

A married woman, æt. 33, applied at St. George's Hospital May 16, 1870. She was suffering from a squint which had come on suddenly five months before. The movements of the right eye were free, but the left eye was fixed in a state of extreme inversion, and could not be rolled outwards even when the right eye was closed. Thirty grains of iodide of potassium were given daily for nine weeks, but little, if any, good resulted from this treatment. On July 19 the tendon of the internal rectus was divided. 'A day or two afterwards, when the conjunctival wound had healed,' the eye was found very much in its old position of extreme inversion, owing apparently to the action of the internal fibres of the superior and inferior recti. The external rectus muscle was then faradised locally by means of a rheophore specially constructed and applied on the conjunctiva over the affected muscle. In this way steady increase of strength was gained, and by November the patient could roll the eye outwards by strong effort to the middle of the palpebral fissure, but only when the right eye was closed. A second operation of dividing the internal recti of both eyes was then performed and with excellent result.

Case VII.

Paralysis of the Serratus Magnus.—This is a somewhat rare and interesting form of local paralysis, and the author is therefore glad to be able to furnish some details of two cases which have come under his own observation.

James S., a married man of slight build, æt. 43, engaged in the timber trade, while unloading a timber waggon on May

19, 1874, over-exerted himself, and says he 'strained his right arm.' The same evening he felt pain in the arm, and had a painful feeling of numbness in the thumb and fore-finger. He seems to have suffered very much, and sought relief at Guy's Hospital, and then at University College Hospital, where he was seen by Mr. Marcus Beck and Mr. Christopher Heath. There was at that time nothing objectively wrong with the arm.

On July 24 Mr. Heath sent the patient to the author. *There was then no sign of paralysis*, but there was considerable pain, especially during the exercise of any of the muscles of his arm. There was distinct tenderness over the brachial plexus, in the axilla, and over the median nerve at the bend of the elbow, but nowhere else. He complained of pain and numbness in the pulps of the thumb and forefinger. There was marked redness (but no glossiness) of the back of the right hand and wrist, and he stated that the skin at the root of the right thumb-nail perspired a great deal. On testing him with both the faradic and galvanic current, there was no sign of impaired or increased irritability of any of the muscles of the right arm; but the skin of the back of the hand, which was preternaturally red, was exquisitely sensitive to the current. States that 'at first he had pain up the side of the neck, and round the blade-bone, and the head was drawn to the right; but this is all gone now.' One of his great difficulties was in stretching out his arm to 'reach invoices from the shelf over his office desk' (a movement which would involve the use of the serratus magnus). He could not do this, he said, because of the pain. On asking him to make this movement, he was restrained by the pain. All muscular acts performed with the right arm were painful, and, as a consequence, performed with some difficulty. Previous to the author seeing him his treatment had consisted of rest in a sling, opium liniment, soap liniment, and, on one occasion, a hypodermic injection of morphia. Nothing, however, had given him any relief except the morphia. The effect of the continuous galvanic current was tried, combined with the exercise of

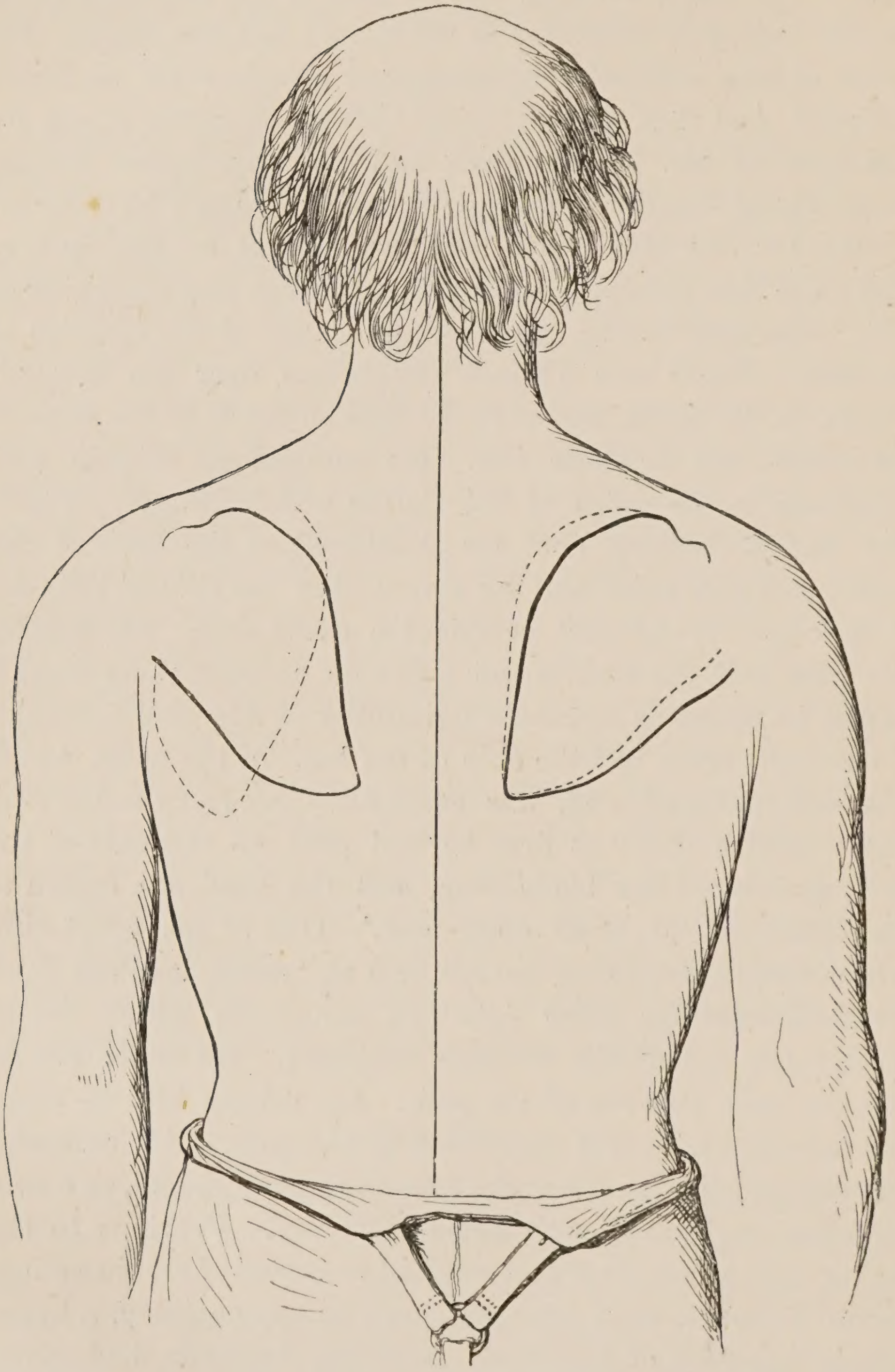

FIG. 21.—The simple lines show the position of the scapulæ when the arms are at rest by the side. The dotted lines show the position when the arms are raised.

those muscles the movement of which caused him pain. The result was most encouraging, and on the first occasion of employing this treatment the relief given was so marked that the patient stated it was like 'waking from a dream.' Not only did the pain disappear, but movements which hitherto had been restrained by the pain—such as the stretching out of the arm—were accomplished without difficulty. After first using the current he was free from pain for many hours, and after a few repetitions of it he seemed to be well, so that on Aug. 1, the fifth occasion of its application, he dismissed himself as well. *At this time there was no appearance of para-*

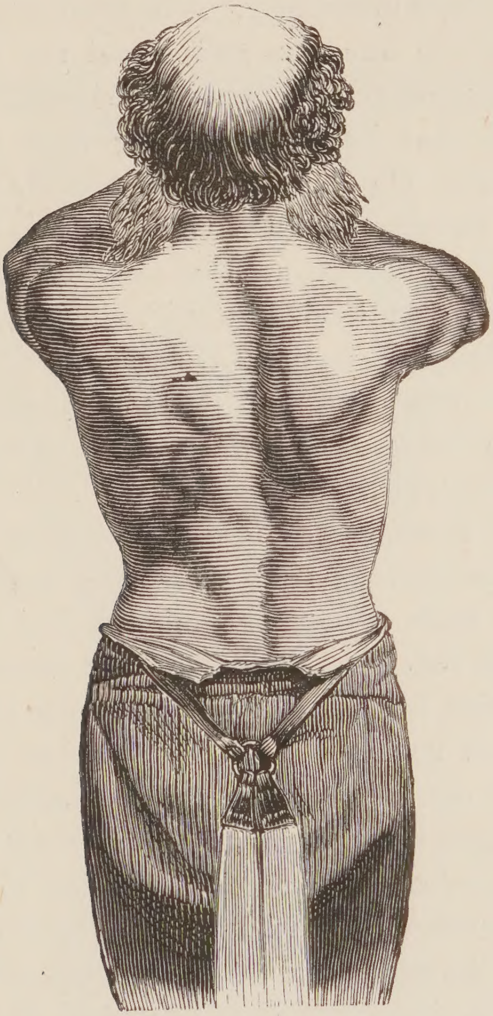

FIG. 22.—Shows the deformity caused by the wing-like projection of the scapula on the side of the paralysis (from a photograph).

lysis of the serratus; the pain and tenderness had gone, but the redness of the hand and the numbness of the thumb and forefinger remained.

On Aug. 20 he came back, saying that his pain had returned three days previously. The pain now was along the external side of the humerus and round the bladebone. On asking him to repeat the movement of stretching out his arm, it was evident that he was suffering from paralysis of the serratus magnus. On Aug. 20 the author left town, and did not return till October, but Dr. Gowers most kindly took the patient under his charge at the Queen's Square Hospital (where, however, he attended very irregularly), and where he received medicine and electrical treatment.

The patient was next seen on Oct. 31, and his objective symptoms were the same as on Aug. 20, and up to the following June the symptoms scarcely altered. With his arms at rest by the side there was hardly any obvious deformity, but close observation showed that the lower angle of the right scapula was a trifle nearer the middle line than the same angle of the left scapula. On asking him to raise his arms to a right angle with his body and in advance of the trunk, a movement which necessitates the full action of the serratus magnus, a very marked deformity was produced; the spinal border of the right scapula starting away from the costal wall and forming a projection about two inches high to the right of the spinal column (Fig. 22). The inferior angle remained stationary, but the upper end of the spinal border approached the middle line in a slight degree (Fig. 21). The two shoulders were on the same level, and there was no obvious difficulty in raising the right arm above the level of the shoulder (Fig. 23).

On inspecting the axillary region, the digitations of the serratus magnus were evident on the left side, but could not be detected on the right.

The effect of the paralysis on the shape of the thorax was remarkable, and was well shown by means of sections of the thorax taken with a leaden cyrtometer at the mid-scapular level

(Figs. 24, 25). With the arms at rest by the side, the sections appeared nearly bilaterally symmetrical; but when the serratus was put in action the symmetry disappeared, the left side bulging laterally, owing to the upward pull of the ribs by the left serratus, while the right side exhibited the projection backwards of the scapula, and very little change besides. The holding of the arms forwards caused great recession of the sternal portion of the chest, due apparently to the backward thrust of the clavicles. With the arms in this position, by placing the hands on the sides of the chest, and asking the patient to inspire

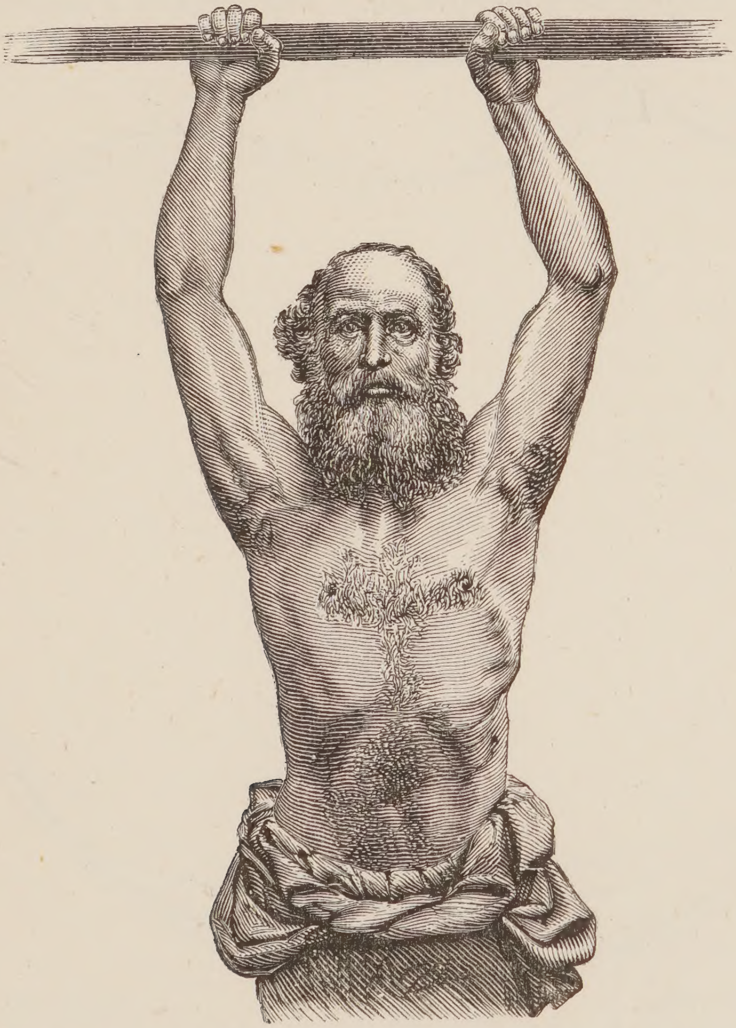

FIG. 23.—Shows the well-developed serratus magnus on the left side, but its entire absence on the right side (from a photograph).

deeply, the diminution of expansion on the right side was easily perceptible. The cyrtometer showed that during deep inspiration the want of symmetry between the two sides of the thorax was very marked. The sternal portion of the chest, which receded when the arms were brought forward, resumed its normal position during deep inspiration. The patient experienced a difficulty in inspiring deeply, and soon tired of doing so. He had also a curious habit of sighing, which may have had some connection with his paralysis.

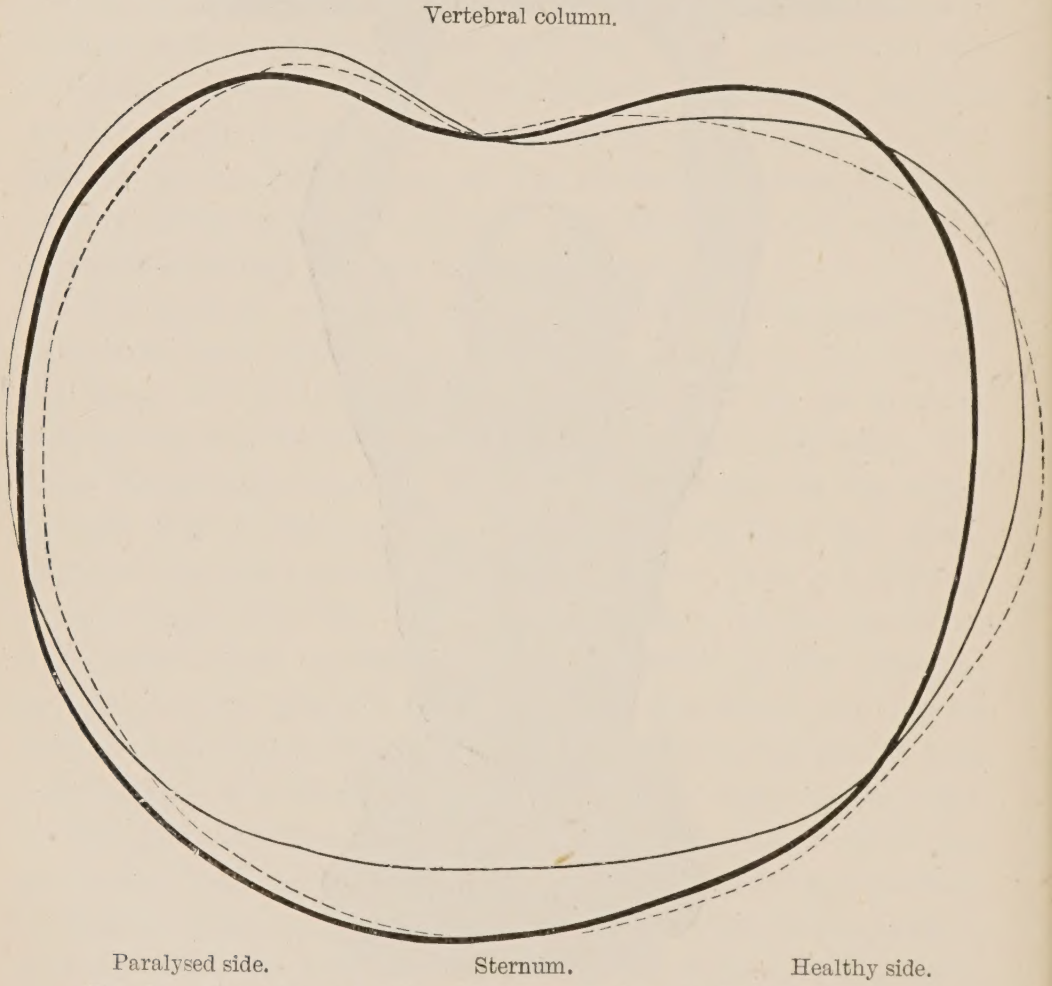

FIG. 24.—The thick and thin outlines are sections of the thorax at mid-scapular level, irrespective of any respiratory act (the thick when the arms are at rest by the side, the thin when they are raised in advance of the trunk). The dotted outline is a section during deep inspiration, with the arms extended.

The paralysed muscle could not be got to respond to any form of electrical stimulus, and was apparently completely atrophied.

His *treatment* was almost *nil.* He was seen occasionally, and was faradised and galvanised, as much for the sake of observation as anything else. The electrical treatment produced no obvious result, but the patient always said that the galvanism 'made him feel stronger,' and came, in spite of discouragement, at regular intervals to ask for its repetition.

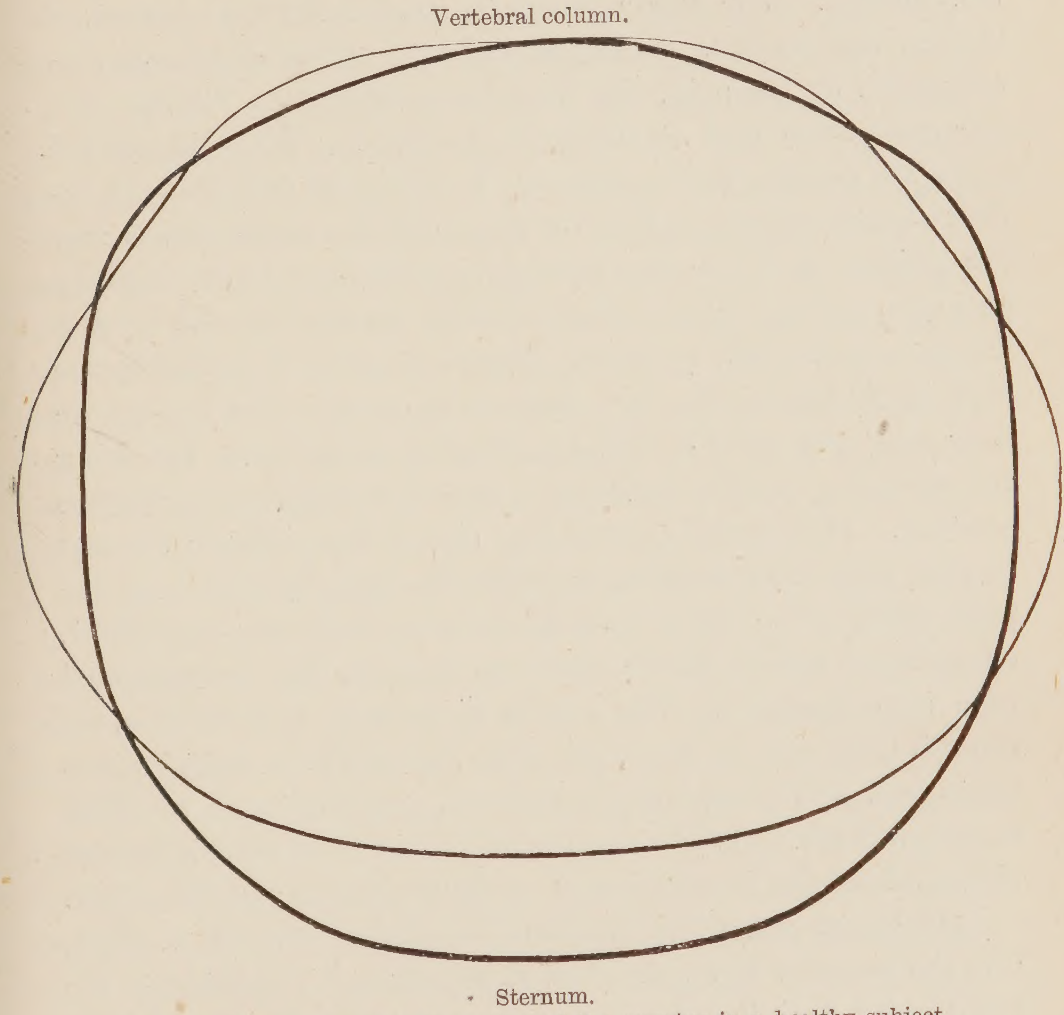

FIG. 25.—Diagram showing the action of the serratus in a healthy subject, irrespective of any respiratory act. The thick outline shows a section of the thorax when the serratus is not in action; the thin outline when it is in full action (the arms being raised in advance of the trunk).

About June the patient 'recovered' rather rapidly, which was due in some degree, the author believes, to the genial weather. At present the movements of the scapula are almost normal, but the atrophy of the serratus still appears to be complete, and it does not respond to either current.

One point of great interest in this case is the time of the appearance of the paralysis, which was not till three months after the date of the mishap to which the patient attributes his troubles. The strain seems to have affected the brachial plexus, and to have caused a sub-acute attack of neuritis, as evidenced by the pain, the tenderness along the nerves, and the congestion and sweating of the hand. Why did not the paralysis declare itself earlier? It might be said that the inflammatory change had begun in one of the nerve trunks, say the median, and creeping slowly upwards had, by an unlucky accident, fallen with undue severity on the special branch which supplies the serratus. That this was not probably the case is shown by the fact that quite early in the history we find pain and trouble while executing movements involving the serratus, thereby making it probable that this nerve was affected. It is possible that the use of the galvanic current in July may have done harm indirectly, and, by removing the pain which was acting as a wholesome check on movement, encouraged action where rest was needed, and so converted pain into paralysis. The case is interesting also because, although there can be no doubt that the serratus magnus was paralysed, and completely paralysed, and although no other muscle was affected, yet the phenomena exhibited by this patient differed from the description given by Duchenne and Niemeyer.

Duchenne says ('Électrisation Localisée,' 3rd edit. p. 939), 'At the moment when the patient separates his arms from the trunk, and mainly when he carries them in advance of him, we see the scapula execute two principal movements—1. A movement of rotation on its vertical axis, so that the spinal border separates itself from the costal wall; 2. A see-saw movement, by which the inferior angle is raised and made to approach the middle line, while the external angle is depressed.'

This last phenomenon was not observed in the patient, but, on the contrary, the upper end of the spinal border was pulled upwards and inwards by the action of the levator anguli, trapezius, and rhomboidei.

Niemeyer (' Text Book of Practical Medicine,' translated by Humphreys and Hackley, vol. ii. p. 336) makes the following statement: 'The serratus is especially required in the act of elevating the arms above a horizontal line, as it then draws the lower angle of the scapula outward and turns the glenoid cavity of the joint upward. It is by this act alone, and not by the contraction of the deltoid, that we are enabled to lift the arm above the shoulder. . . . The patient is unable to lift his arm above a horizontal line, and is thus rendered extremely awkward. Anyone who has often watched a patient with this affection put on or take off his coat or shirt, will be able to make a diagnosis in the next case he meets with from these acts alone.' An inspection of our patient showed that although the chief signs of the paralysis were too well marked to admit of any doubt as to its presence, yet he could raise his arm and put on his coat without much difficulty.

It may seem a paradox to state that the patient 'got well,' but did not recover. His improvement was due, the author believes, not to the recovery of the serratus magnus, but to the compensating growth of other muscles which serve to keep the scapula in its place (the rhomboidei, trapezius, &c.).

The case presented a marked contrast to another case of paralysis of the same muscle, which the author was enabled, by the kindness of Mr. Carsten Holthouse, to bring before the Clinical Society. The second patient was a man æt. 28, who had fallen upon his back a couple of months previously, and who, in addition to the wing-like projection of the scapula, suffered to a marked degree from that inability to raise the arm above the shoulder upon which Niemeyer insists. On examination it was found that not only had there been no compensating hypertrophy of the trapezius and rhomboids, but (as the result of direct violence probably) there was well-marked wasting, certainly of the trapezius (upper part), and probably of the rhomboidei, as evidenced by a smaller mass on the right side as compared with the left over the situation of the rhomboidei when these muscles were put in action.

Both these patients were exhibited to the members of the Clinical Society, the one on Feb. 12 and the other on Feb. 26, 1875, and the above histories are contained in the 8th volume of the society's 'Transactions.'

Two cases of paralysis of this muscle are reported by Mr. Owen and Mr. Knott, of St. Mary's Hospital, in the 'British Medical Journal' for March 6, 1875. The first case was that of a woman, æt. 39, in whom the symptoms of paralysis, which were well marked, had gradually supervened. The muscle, however, responded readily to faradisation ('one pole was placed in the root of the neck, near the origin of the nerve of Bell, whilst the other was applied along the costal attachment of the serratus magnus'), and after two months all pain and deformity disappeared, and she was discharged cured.

The other case was that of a boy in whom the deformity was double, although most marked on the right side. Treatment by faradisation was in this case also duly followed by recovery. The woman had been furnished by a 'surgical mechanician' with an apparatus to keep the shoulder-blade in its place, but necessarily without any benefit resulting.

Case VIII.

Syphilitic Paralysis, with unusally rapid Wasting and Repair of Muscles.—The 6th volume of the 'Clinical Society's Transactions' contains the following case, recorded by the late Dr. Anstie.

John C., æt. 32, a coachman, with a doubtful history of syphilis, suffered in 1870–71 from double vision and ptosis, for which he was treated with iodide of potassium and blisters, and from which he never completely recovered.

During the winter of 1871–72 suffered from 'rheumatic pain' in the back and outside of the right upper arm, and found a rapidly increasing loss of the power of extension. In February 1872 noticed that the muscle at the back of the arm was 'wasting away.' In June 1872 he applied for advice to Mr. Lawson, who sent him to Dr. Anstie. 'At this time the whole flesh on the posterior aspect of the arm had almost entirely atrophied away: there was scarcely any muscular substance of the triceps remaining; still, the few fibres that remained responded fairly well to the induced electric current. So little voluntary power remained that extension of the arm could be resisted with a single finger. The loss of power was almost confined to the triceps, but the man complained that when the hand got cold there was a numbness and some weakness in the index finger and thumb. From the middle of July to the middle of September he was faradised by Dr. Anstie himself, at first every day and then three times a week. The power and size of the triceps increased very rapidly. Soon after treatment was commenced it was noticed that the extensors and flexors on the back and front of the fore-arm had begun to waste, as well as the pectoralis major and (in a slight degree) the deltoid. Faradism was locally applied to each of the wasting muscles. The patient also took iodide of potassium, and in October was 'very nearly well and expecting to resume work.' Dr. Anstie directs special attention to the rapidity of wasting and repair in this case. 'The mass of flexor muscles on the front of the fore-arm lost bulk to such an extent that you might have put a fair-sized walnut and a half into the cavity, and this cavity was again nearly filled up within the space of not much more than three weeks.' The extensors and pectoralis underwent changes almost as rapid. 'Some of these processes took place after the iodide of potassium had been altogether suspended, and therefore cannot have been influenced by that agent.' Dr. Anstie does not attribute all the curative effect to faradism, but concludes that the 'therapeusis was in part spontaneous.'

Where *toxic agents* (such as lead) are the cause of paralysis it is presumable that the paralysis is due to their presence in the paralysed tissue. The paralysing matter has but a poor chance of elimination so long as the muscles remain inactive and molecular change is at a minimum. The enforced action of the muscle must have the effect of removing the poisoned molecules, and (supposing the patient to be no longer exposed to poisonous influences) supplying their places with healthy ones. There is hardly any form of paralysis which is so quickly benefited by electricity as lead palsy. The galvanic current is of the greatest service, and the author has seen several cases in which a very few applications of it have resulted in very material improvement.

Sir W. Gull records eight cases of lead palsy in his report, all of which were largely benefited by taking sparks not only from the paralysed muscles, but from the cord as well. As to its mode of action, it is thought probable that electricity may 'oppose the depressing effect of lead,' but is probably mainly useful by 'tracking closely the footsteps of depuration and awakening the energies of the wasted tissues on the removal of the poison.'

Hysterical Paralyses are peculiarly amenable to electrical treatment, and by means of it we may often work apparent miracles when every other means has failed to afford any relief. We would caution the student against regarding these paralyses as cases of '*sham*.' They are nothing of the kind; and although we cannot be sure that any central lesion exists, we very frequently find evidence of peripheral lesions in the form of wasting of the muscles, loss of electric irritability, and cutaneous anæsthesia. Although the cause of the paralysis may be purely emotional in the first instance, yet, if the paralysis endure for any time, the loss of power may become not only genuine but considerable. No patients are so completely powerless as the victims of hysterical paralysis; and the author has attempted, in the chapter on diagnosis, to account for the wasting and loss of irritability in the muscles affected. The faradic current is of most service in these cases, but it must be used with judgment, with perseverance, and with kindness. He who thinks that it is sufficient merely to give pain will often fail, and, should the patient suspect his tactics, she will to a certainty grow worse. Those muscles which are the seat of paralysis must be systematically faradised, and when a patient who has no will to move the muscles sees that her muscles can be made to contract even in opposition to her will, it is not surprising that such a discovery should exercise a wholesome influence over her mental condition. At the Royal Infirmary for Children and Women the author has had many opportunities of seeing the beneficial effects of electricity in very obstinate cases of hysteria. He is inclined to think, also, that the atmosphere of a children's hospital exercises a most wholesome influence on the moral condition of hysterical women, since nothing is more calculated to draw these patients 'out of themselves' than the sight of suffering childhood. For the brief notes of the following case the author is indebted to Mr. W. O. Day, the house surgeon.

Case IX.

Hysterical Paralysis and Spasm.—A. G., aged 27, single, was admitted to the Royal Infirmary on April 20, 1875. The patient stated (but her statements are to be received with caution) that she had been an inmate of a convent, and, while there, had had an illegitimate child. Her confinement was in August 1874, and was followed by pelvic abscess. She had kept her bed since her confinement, owing to her paralysis. There was complete uselessness of the right hand and leg, and, in addition, some tremor and spasm when attempts were made to move them. The tongue protruded to the left; there was marked tenderness in the lower dorsal region of the spine, and the patient further complained very much of headache. No appearance of catamenia since confinement; no signs of any previous pelvic cellulitis were detectable. Tongue furred; bowels obstinately confined. She was ordered mercurial purgatives and systematic faradisation of the arm, leg, and tongue. In a fortnight she was walking about, and in a month she was able to do needlework, which she had not done for ten months previously. In July, after the passage of galvanic currents through the ovarian region, she menstruated slightly, and soon became quite well.

In those cases where the limbs are cold, blue, and ill-nourished, the galvanic current is often of very great service. Faradisation with a wire brush is often effectual in removing the condition of anæsthesia.

We may summarise the chief facts to be borne in mind while treating paralysis with electricity, in the following rules, which have been in part culled from Dr. Reynolds' treatise 'On the Clinical Uses of Electricity':—

1. *If the paralysis to the will remain absolute, and if the contractility of the muscles be perfect, we do no good by persevering with electrical treatment.* This condition is often met with in hemiplegia. The patient is absolutely helpless on one side, although the muscles are in no degree wasted, and their irritability remains normal.

2. *If the paralysis to the will remain absolute, and if the irritability of the muscles be diminished, then electricity is useful, in so far as it helps to improve the nutrition of the muscles, and restore their normal degree of irritability.* The normal degree of irritability being restored (the paralysis to the will remaining absolute), then electrical treatment may be discontinued. The irritability of muscles may be diminished from mere want of use, and electricity may serve to restore this irritability.

3. We should bear in mind the advice of Sir Thomas Watson, that 'our aim should be to preserve the muscular part of the locomotive apparatus in a state of health and readiness, until, peradventure, that portion of the brain from which volition proceeds having recovered its function, or the road by which its messages travel having been repaired, the influence of the will shall again reach and reanimate the palsied limbs.'

4. Whenever we meet with the *degenerative reactions* we should employ that form of current to which the muscles most readily respond, which is invariably the galvanic. We must persevere doggedly, and we may find our perseverance rewarded by the gradual return of the normal muscular irritability.

5. If the irritability to both forms of current has completely disappeared, we are not justified in persevering too long, nor in holding out delusive hopes. Nevertheless, treatment should not be abandoned without a patient trial.

In treating all forms of chronic paralysis we must bear in mind that we generally have to do with one of two conditions :—

1. We may have a permanent paralysing lesion. In this case no amount of electrical treatment will remove that lesion. We may, however, do good to the deformities and muscular atrophies which result from that lesion, and by so doing we may be able to save the patient a certain amount of discomfort and suffering. If there are no deformities or atrophies, we can have no grounds for prolonging an electrical treatment.

2. The paralysing lesion may have disappeared, but its effects may remain in the shape of atrophied muscles and deformities. In these cases electrical treatment is our sheet-anchor, and is not to be replaced by any other therapeutic agents, and by it we can often restore the patient to perfect health.

Amongst the undoubted and invaluable uses of electricity may be reckoned its employment for the production of *artificial respiration.* Inspiration depends mainly upon the descent of the diaphragm, and if we can bring this about by acting upon the 'motor point' of that muscle, we shall cause a volume of air to enter the lungs far greater than that which can be made to enter by any other artificial means.

In all cases where artificial respiration is indicated—chloroform accidents, drowning, suffocation, &c.—the faradisation of the phrenic nerves may be had recourse to, and if such faradisation be not delayed too long, and if it be properly applied, inspiration is sure to follow its employment.

In cases requiring artificial respiration, every moment is of importance, and Sylvester's method of producing it should in all cases be at once resorted to while the faradising apparatus is being sent for, or is being got ready for use. When the faradising apparatus is ready, faradism may be superadded to Sylvester's method. Artificial respiration should always be performed gently, thoroughly, and not too quickly, the object being to imitate the natural process. Lay the patient flat on a table, with the neck thoroughly extended and the head turned to the left side, so as to prevent the tip of the tongue from falling against the roof of the mouth and acting as an obstructive valve, and so that the right phrenic nerve may be reached with the rheophore in the manner indicated, while treating of the application of electricity.

One person should carry out Sylvester's method, while another attends to the faradisation.

Sylvester's method, if properly performed, will always cause the ingress and egress of air from the lungs, no matter how long the patient may have been dead; and the person who is entrusted with the carrying of it out should not be satisfied unless he hear the passage of air through the windpipe every time that he presses the arms against the thorax, or raises them above the head. The person who has charge of the faradisation should stand on the right side of the patient, and should press one rheophore well down on the phrenic nerve in the neck, and then, when his coadjutor raises the patient's arms, to cause inspiration, he should place the second rheophore on the right side of the thorax, on a level with the sixth intercostal space. When the patient's arms are depressed again, he should remove his thoracic rheophore, and make connection when they are again pulled above the head. This should be repeated not more than about twenty times in a minute. If it is effectual, a distinct loud rush of air should be heard whenever the circuit is made.

Too strong a current must not be used. A current of such strength as will produce contraction of the muscles of the ball of the thumb should be sufficient.

Some writers advise that the rheophores should be placed upon either side of the neck, on the motor points of the phrenic. We do not recommend this, because of the risk of irritating the pneumogastric nerves too strongly, and so causing the stoppage of the already feebly-acting heart. It is not advisable to put either rheophore near the heart. If we can get fresh supplies of oxygen into the lungs, the action of the heart will gradually return to its normal condition, provided the patient be not past recovery.

We may now briefly pass in review some of the chief diseases and symptoms for the relief of which the stimulating action of electricity has been employed.

Attention has lately been drawn to the treatment of *Rheumatoid Arthritis* by electricity. It is stated that, in this disease, the galvanic current transmitted from the spinal column to the epigastrium acts as a general tonic, and quickly improves the condition of the patient. Dr. Althaus has had good results from this method of treatment. The deformity of the joints has been diminished, the pain has been annulled, and sound rest has taken the place of sleepless nights. The author has had no experience in the treatment of true deforming, chronic rheumatoid arthritis, such as generally occurs in anæmic subjects, but has lately had under his charge a case which more resembled gout than rheumatoid arthritis, and which seems to have benefited by electrical treatment, locally applied.

CASE X.

'*Rheumatic Gout' affecting the left arm and hand.*—The patient was a gentleman sixty-four years of age, active, and of a full habit of body. Three months previously he had been attacked somewhat suddenly and severely with 'rheumatic gout,' which had affected the shoulder, elbow, wrist, carpal and phalangeal joints of his left upper extremity. The elbow was least affected. There were no chalky deposits anywhere about the body. Neither the great toes nor any other joints, except those named, had been attacked, and he had had no previous seizures. He was liable to attacks of acid dyspepsia, and his urine was occasionally loaded with lithates, but contained no albumen.

When he came under observation the pain, which at first was so great as to prevent all movement and confine him to his bed, had much diminished, excepting towards evening, when he was liable to slight exacerbation of his troubles.

The shoulder was somewhat stiff and painful on movement; the elbow had completely recovered; the wrist was considerably swollen and absolutely stiff; the hand was pronated and could not be supinated; the hand and fingers were *immensely swollen*, so as completely to obscure their anatomy; the fingers were extended, tense, shiny, presenting none of their natural wrinkles, absolutely stiff, pale, and cold. The nails were dry and perfectly white. The fore-arm was markedly flabby, and the nutrition of the whole arm was wretchedly bad. There was a considerable amount of anæsthesia of the front of the fore-arm and back of the hand, and the irritability of the flexor muscles of the wrist and fingers and the intrinsic muscles of the hand—as tested by faradisation—was very much below par.

It is probable that, in this case, the inflammatory exudation had not only crippled and stiffened the joints, but had invaded the sheaths of the tendons and other tissues, and being in sufficient quantity to distend the skin of the hand very considerably, had probably, by pressure, interfered with the vascular supply of the fingers, and, by implicating the nerves, had lessened the cutaneous sensibility and brought about a lowering of the muscular irritability. The indications in this case seemed to be—(1) to quicken the nutritive activity of the limb, and so hasten the absorption of the effused material, and (2) to restore the lost irritability of the muscles, for if this were not quickly restored, it was evident that the joints would become subjected to unequal muscular action, and the chances of deformity ensuing would be thereby increased.

To restore the nutritive activity, the galvanic current was employed, and the whole limb, and especially the hand, was thoroughly sponged with the negative rheophore, the positive being held in the patient's other hand. The first two applications were without any appreciable effect, but the third produced thorough redness of the hand and fingers. This was followed by a rapid subsidence of the swelling and the reappearance of the natural wrinkles and the healthy tint of the fingers, so that, in about a fortnight, the hand, although still stiff, had resumed its natural aspect. The muscles were faradised, especial attention being paid to the interossei and the muscles of the ball of the thumb. Their irritability rapidly returned, as did also the cutaneous sensibility. With the disappearance of the swelling and the restoration of the muscles to their healthy condition, the movement of the stiffened joints rapidly improved. At first the irritability of the muscles to faradisation was very much below par, and the services of a skilled professional shampooer were called in, and it was remarkable how very rapidly the irritability of the muscles improved after rubbing. The power of the patient's hand was tested almost daily by means of a dynamometer, and it was found that the immediate effect of faradisation was to increase the power, apparently by rousing all the dormant fibres of the damaged muscles. Although the effect of the rubbing was undoubtedly to increase the *irritability* of the muscles to faradism, it was found that generally the *immediate* effect was to *decrease* the power of the hand as measured by the dynamometer. The rubbing apparently exhausted the muscles for a time. The following table gives an accurate idea of these facts :—

Date	Power of band in lbs.			
1874.	Before rubbing.	After rubbing.	Before faradism.	After faradism.
May 16	7	5	—	—
17	—	5	—	—
18	—	—	—	10½
20	—	9	—	9

Date.	Power of hand in lbs.			
1874.	Before rubbing.	After rubbing.	Before faradism	After faradism.
May 21	11	7	—	11
22	—	9·5	9	11
23	10·5	9 5	10·5	14
25	10	10	—	—
27	10	11	11	15
28	10	10	10·5	11·5
29	10	9·5	—	15·5
30	10	10·25	—	—
June 1	—	10	10	15
2	15	10	—	—
3	15	12	—	15
4	15	14	14	15
5	15	15	15	17
6	15	12	9	16
8	15	15	9	17
9	15	15	—	15
11	16	15	—	17
12	—	—	—	18·5
13	15	15	10	15
15	—	18	16	16
16	15	15	—	—
17	—	15	—	—
18	—	17	—	—
19	20	17·5	18	20
20	—	16	—	—
22	—	15·5	—	—
23	20	17	15	21
24	17	15	—	—
25	20	18	—	—
26	—	15	—	—
27	20	15		

Dynamometrical records were carefully kept, for several months, and the following is the result:—

In May, 27 trials with the dynamometer gave an average of 9·97 lbs.
,, June, 67 ,, ,, ,, ,, 15·6 ,,
,, July, 39 ,, ,, ,, ,, 19·0 ,,

In July the patient went to Buxton, where he continued the rubbing, and also took a course of baths. Faradism was discontinued.

In August, 41 trials with the dynamometer gave an average of 22·26 lbs.
,, September, 44 ,, ,, ,, ,, 21·65 ,,
,, October, 18 ,, ,, ,, ,, 22·16 ,,

On October 10 patient left Buxton, and returned again on November 11.

In November, 27 trials with the dynamometer gave an average of 28·0 lbs.
,, December, 24 ,, ,, ,, ,, 26·9 ,,

At the end of December the patient again left Buxton.

In January, 20 trials with the dynamometer gave an average of 30·8 lbs.
,, February, 26 ,, ,, ,, ,, 32·5 ,,

The dynamometer is of little service for the measurement of actual power, but for purposes of comparison and for marking the progress of a patient, it is of decided use.

Labour.—Dr. McRae, of Penicuik (‘Edinburgh Medical Journal,’ September 1873), recommends the use of faradisation in the second stage of labour, and quotes cases to show that, after the failure of other means, the current quickly succeeded in producing activity of the uterus. One rheophore is applied to the abdominal parietes, and the other to the perineum. Dr. McRae also recommends this treatment in cases of post-partum flaccidity of the uterus, or post-partum hæmorrhage, as well as for the expulsion of clots from the uterus, and in cases of uterine hæmorrhage caused by the pressure of fibrous tumours.

Dr. Martemucci prefers electricity to ergot when there is inertia of the uterus during labour, for the following reasons:—

1. That the contractions are more under control; 2. That there is less danger to the fœtus from continued pressure on it and the placenta; 3. When using ergot the uterus cannot enjoy those periods of relaxation which are so necessary to it.

Dr. Martemucci has also found electricity of use in the hæmorrhage attending placenta prævia.

Amenorrhœa.—To apply electricity indiscriminately for the cure of that which is but a symptom of many and varied pathological conditions would seem to be at once unscientific and absurd. It was formerly the custom at Guy's Hospital (in 1837–41) to treat amenorrhœa by means of shocks sent through the pelvis from a Leyden jar. 'I think,' says Dr. Wilks, 'it is very questionable whether the discharge of the Leyden jar was of any value in amenorrhœa, and indeed it could be scarcely expected, seeing that the arrested function of the uterus is often due to some more general change in the system.' However much we may feel Dr. Wilks' scepticism to be just, we feel that the published facts are too remarkable to be passed over.

Dr. Golding Bird ('Guy's Hospital Reports,' 1841) says, 'Scarcely any cases have been submitted to electrical treatment in which its sanatory influence has been so strongly marked as in those in which the menstrual function was deficient. . . . So long as the patient is seriously out of health, as when marked symptoms of chlorosis are present, scarcely the slightest benefit has ever resulted from the employment of electricity; in fact, as this agent can in these cases be regarded but as a local stimulant applied to an organ whose function is deficient, we could hardly expect the menstrual discharge to appear, when, from the deranged state of the general health, the womb is not in a state to supply the deficient secretion. The rule for insuring success in the great mass of cases of amenorrhœa is sufficiently simple :—Improve the general health by exercise and tonics; remove the accumulations often present in the bowels by appropriate purgatives, and then' (having previously determined that no physical obstacles to menstruation are present) 'a few electric shocks, often a single one, will be sufficient to produce menstruation, and at once to restore the previously deficient function.'

Dr. Bird gives a table of twenty-four cases of amenorrhœa, varying in duration from three months to three years, and in age from fourteen to twenty-five. Of these twenty-four cases twenty were cured, 'the influence of the *electrical* treatment being very remarkable.' The menstrual flow appeared often within a few hours, and at most a day or two, after the employment of electricity, which would seem to have played very much the part of that impulse to the pendulum which is necessary to set going a clock which has already been wound up.

Of the four unsuccessful cases all were chlorotic, and three of them had never menstruated.

Of twenty-three cases reported by Sir W. Gull in his report (1852), no less than fourteen derived great benefit from electrical treatment.

Amongst other novel uses of electricity may be mentioned the removal of *jaundice* by the faradisation of the gall-bladder. This is applicable only to cases of jaundice depending upon obstruction to the outflow of the bile through the common duct.

Skin Diseases, Treatment of by 'Central Galvanisation.'—Messrs. Beard and Rockwell, in the 'New York Medical Record' for August 15, 1873, give details of some cases of skin disease treated by central and local galvanisation and faradisation. 'During the past two years,' they say, 'we have treated cases of eczema, prurigo, and acne by central galvanisation alone, without making any application to the diseased surface whatever; and under this method of treatment the results have, in some instances, been more satisfactory than under any other method of using electricity in these affections. Their method is to place the negative pole to the epigastrium, and the positive to the back, moving it by turns along the whole extent of the cerebro-spinal axis, thus, as they say, 'bringing the whole central nervous system under the influence of the current.' Among the cases, they record one of an Irish servant, aged fifty-one, with chronic eczema of the leg of eight years' standing, which, having resisted the known methods of treatment, was cured in two months by central galvanisation. Great relief from the itching is in all cases afforded by this method of treatment. The troublesome itching of prurigo has also, it is said, been relieved by it.

In a paper on *Acne Rosacea*, in 'The Practitioner' for July 1874, Dr. W. B. Cheadle says:—

'Arguing from the pathology of the eruption, and the good effects observed to be produced by local stimulants, that the power of electrical stimuli in exciting prolonged contraction of the small vessels, as observed by Mr. Wharton Jones, ought to be of service in this disease, I was led to try faradisation of the surface of the skin. By the kind assistance of Mr. Knott, the registrar of St. Mary's Hospital, I have been able to use it in four cases of moderate severity. A current of medium intensity was applied for about ten minutes twice a week, the negative pole[1] being passed slowly over the whole of the affected surface. The first effect was to cause a bright redness of the part operated on, and increased sensation of burning. The latter passed off in the course of an hour or so, and the patients declared that the uncomfortable heat of face was greatly less during the following day than it had been previous to faradisation. Although the general flushing of the face was temporarily increased, it was observed that the varicose and dilated vessels which marbled the face, and which were in one case carefully examined with a lens before and after faradisation, on three occasions were notably contracted by it. Many which were very conspicuous to the naked eye before the operation were comparatively indistinct and obviously reduced in calibre immediately afterwards. At the next visit there was unquestionably an appreciable improvement, the colour of the face being less bright, and the gutta paler and less distinct.

'In three of the cases the eruption had so far faded after treatment by this method for from two to three months, that the patients professed themselves sufficiently cured, and ceased to attend. The fourth case is still under observation; the patient has repeatedly appeared almost well, and has then ceased to attend for a time, returning with a relapse in the course of a few weeks, and always improving steadily on the regular application of the remedy. These cases are too few to build upon with certainty, but the results have been sufficiently striking and satisfactory to induce a further trial of faradisation in the treatment of acne rosacea.'

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[1] This mention of the *negative pole* when speaking of *faradisation* requires explanation.

Chilblains.—Dr. Balfour, of the Royal Military Asylum at Chelsea, recommends faradisation as a remedy for chilblains. The relief afforded has been so decided 'as to leave no room for doubt of its efficacy.'

Optic Nerves, Anœmia of.—Dr. R. J. Pye Smith, in the 'British Medical Journal' for May 18, 1872, records the results of galvanisation when employed for 'amblyopia and amaurosis associated with anæmia of the optic nerve (white optic disc).' Six cases are recorded, in one of which there was 'considerable improvement' after twenty-three days' treatment, and in another, 'slight but decided improvement,' after seventeen days' treatment. The other four gave negative results. The negative rheophore was placed behind the ear, while the positive was applied to the closed eyelid of the same side, or to the brow. The number of cells (Daniell's) employed was just sufficient to produce a flash.

'Ophthalmoscopic examination' (which could necessarily only be made when the positive rheophore was applied to the brow) 'during the passage of the current showed in all cases the veins of the retina to be congested after the first second (during which they sometimes appeared to be partially emptied), and to remain so till the interruption of the circuit, when they gradually resumed their natural fulness. This effect was observed even when no flash was perceived by the patient.' The patients were in-patients of Guy's Hospital, under the care of Mr. Bader. One of the cases seems worthy of quotation:—

CASE XI.

Anæmia of Optic Discs (reported by Dr. Pye Smith).—'J. L., aged forty-two, a wheelwright, was admitted December 12, 1871. His general health was good, except for an attack of quotidian ague twelve years ago. He had been in the habit of smoking about two ounces of "shag" per week. His sight began to fail nearly five years ago. He went to the Ophthalmic Hospital, and attended as an out-patient for three years, taking medicine daily. . . . He came to Guy's Hospital as out-patient nearly two years ago, when both optic discs were found to be white; he had attended ever since, giving up smoking, and taking $\frac{1}{3}$ grain of pil. opii three times a day. His sight had continued to become worse. During the last year he had felt ill and nervous. Since his sight began to fail he had had about half-a-dozen attacks of frequent shiverings, followed by vomiting, lasting for a day or two and then passing off. On admission he was very tremulous. He could just distinguish windows with each eye, but could not count the panes. He considered the right his best eye. He stated that he saw best in a dull light, and that he was able occasionally to see the time by a large clock for a minute or two, and then the sight became dim again. The tension of the right eye was (?) slightly above the normal. The pupils were dilated and sluggish. On ophthalmoscopic examination both eyes were found hypermetropic. The right optic disc was well defined, bluish white, with very white centre; its vessels were slightly displaced to the nasal side; the arteries were small and few. The left optic disc was well defined, bluish white; the arteries were very small and few; the veins few and half empty. The retina was rather anæmic. There was small floating opacity in the vitreous body. Both eyes were galvanised twenty-three times—*i.e.* on twenty-three different days; each day, as before stated, the current was passed about six times through each optic nerve. A battery of twenty elements was used. A flash was usually perceived on closing the circuit, and a 'dark flash' on opening it. Occasionally slight headache was produced, but the trembling disappeared in a week or so. After the fourth application the patient was able to see the seats in the grounds: after the seventh he could count the panes of a window upwards, but not from side to side; after the seventeenth application he was able to read 'Operation Room,' painted in letters about three inches high, over a door in the ward. He could now always see the time by a large white-faced clock, and could see his way about the grounds much better than at first. On January 18 he was seized with one of his attacks of vomiting, shivering, and loss of appetite. The sight was a good deal impaired for several days, but the galvanism was continued, as he was very anxious for it. His sight was examined again on January 31. He could now see the paths in the grounds, people as he met them, a white stone sun-dial out of doors, the time by the clock, and could count the panes of a window in both directions with either eye. Ophthalmoscopic examination showed no marked change.

Mr. Kiddle, of Guy's Hospital, reports that his results with galvanism, when used for anæmia of the optic nerve, had been, on the whole, 'entirely unsatisfactory;' 'at times there appeared to be some improvement of sight, but this was soon followed by a relapse, and I attribute the improvement more to the general health of the patient than to any benefit derived from galvanism.' Out of eleven cases none had received decided benefit.

A writer in the 'Lancet' for September 19, 1874, says, 'In a recent note in the "Recueil d'Ophthalmologie," M. Onimus brings forward observations on cases of atrophy of the optic nerve treated with good effect (by galvanism) . . . M. Onimus uses only the constant current. . . . His method consists in the application of the rheophores of a somewhat weak battery over the upper part of the neck, one on each side, so as to act only on the superior cervical ganglia, and thus to influence the intra-ocular circulation. That it is affected by this, as by other methods, is shown by the occurrence of a phosphene or flash at the moment of closing or opening the circuit, and also by the momentary contraction, followed by the dilatation of the retinal vessels, as seen with the ophthalmoscope. . . . With regard to the results of this method, M. Onimus very properly distinguishes between cases of atrophy due to cerebral or spinal disease, or associated with ataxic symptoms, and those in which it is primary and uncomplicated. Five instances of success are detailed, out of thirty cases of the former class in which it was tried ; in the successful cases, the ataxic symptoms were for the most part slight, and in an early stage. The benefit obtained was, however, very marked, both as regards definition and extent of the field of vision. The current was usually applied every other day for six or seven weeks. In simple cases much better results may be looked for.'

Insanity.—Dr. S. W. D. Williams (Report of the Sussex Asylum, 1872) has found galvanism most useful in cases where there was much excitement with depressed bodily functions—the mania of weakness. He applies the positive pole to the head, and uses Stöhrer's battery, the number of cells varying with the strength and condition of the patient. Eleven cases are enumerated in which the electricity was employed, three male and eight female. In five of these cases the effect of electricity seemed to be marvellous and veritably curative after every other means had failed—*e.g.*, 'A female aged fifty, married, had been insane seventeen months, with melancholia with excitement. Her bodily health was impoverished. She was treated with chloral, ergot, morphia, bromide of potassium, and cannabis indica, cold and warm douches, wet sheet packing, and other remedies. She began to evince a tendency to dementia. Electricity was then employed, and she improved, and could shortly be discharged.'

In some cases there was no mental improvement. In one, improvement took place at first, but did not continue. ('London Medical Record,' July 2, 1873.)

Dr. Beard recommends 'central galvanisation' for insanity.

Dr. Rockwell also has employed 'central galvanisation (cathode to epigastrium and anode to vertex of head or spine) for various mental conditions, and, it is stated, with success.

Diabetes.—Since diabetes has been referred to a pathological condition of the sympathetic nerve, electricity has frequently been employed for its treatment. The author has been enabled to make observations on two cases in Charing Cross Hospital, but in neither of them was any positive effect produced on the amount of sugar in the urine. The first was a case of Dr. Silver's. The patient was a man past middle age, who had suffered some years from diabetes mellitus, and the effect was absolutely negative. In the second case, which was placed at the author's disposal by Dr. Julius Pollock, accurate observations were made, the results of which (thanks to the industry of Mr. Owen, the clinical clerk) are appended. The results of the electricity, as regards the amount of urine and its specific gravity, are scarcely appreciable, but it will be observed that subsequent to the first application of galvanism there was a slight diminution in the average amount of urine, a slight elevation of temperature, a decided increase in the rate of pulse and respiration, and a slight increase in the specific gravity of the urine after fermentation. All these results, however, were slight in degree.

Case XII.

Diabetes Mellitus.—The patient, who was a young man aged twenty-five, invariably stated that the galvanism made him feel stronger and less languid, and, like many other patients who are subjected to the continuous current, he seemed discontented when its application was discontinued.

The result of the treatment of this case is set forth in the accompanying table:

CASE XII. (*Diabetes Mellitus*).

Date	Temperature		Amount of urine in CC	Specific gravity		Amount of urea, in grammes	Diet in previous 24 hours	Weight		Pulse	Respiration	Observations, treatment, &c.
	Morn.	Even.		Before fermentation	After fermentation			st.	lbs.			
Feb. 10	99·6	99	6500	1037	1005	39 2	Was eating ordinary diet up to 5 A.M. on the morning of 12th. Previous to admission had been taking diabetic diet. On the 13th began with gluten bread, meat, 4 eggs, beef-tea, and water.			60	16	Mistura camphoræ.
11	98·8	98	6300	1039	1005	50·4						
12	97·6	99	7100	1040	1005	58·95						
13	98	97 4	7300	1040	1005	58·4		9	8			
14	97·4	98	3200	1025	1011	41·6		9	10	57	15	
15	97	97 4	3200	1029	1008	42		9	11½	58	13	
16	97	97	4303	1029	1008	47·3		9	10	66	13	
17	97	98	3207	1023	1010	32		9	7	64	13	
18	97·6	98·4	5202	1029	1009	54·6		9	6	62	12	Pil. Rhei Co. gr. x.
19	97·6	97	5006	1030	1010	52·5		9	4	52	12	
20	97·6	98	5802	1034	1010	75·4		9	5	54	12	
21	97	98·4	5803	1038	1014	98·6		9	5	60	12	
22	97	97	5300	1039	1013	79 5		9	5	61	12	
23	97	97·10	5100	1041	1013	81·6		9	5	61	12	
24	97	98	5100	1038	1015	86·7		9	5	62	12	
25	98·6	98	5400	1039	1014	97·2		9	5	64	12	
26	97	98	5300	1042	1027	90 1		9	6	64	12	
27	98	97·10	6208	1041	1008	93		9	5	64	12	
28	97	98	6200	1040	1008	93		9	7	63	13	
Mar. 1	97	98	5208	1042	1007	88·4		9	9	64	13	
2			6208	1042	1010	86 8		9	10½	64	15	

3	97	97·2	5200	1039	1009	72·8		9	9	65	15	Galvanic current commenced, with positive pole applied to spinal cord and negative pole to abdomen.
4	98	97·3	5006	1038	1008	70		9	8	86	15	
5	98	97·3		1038	1009	91·5		9	8	66	15	
6	97	98	5000	1038	1008	86·5		9	8	78	15	
7	98	99	5800	1036	1008	81·2		9	6	78	16	
8	97·3	98	5200	1040	1015	72·8		9	5	80	16	
9	97·4	99	5300	1041	1014	68·9		9	6	64	15	
10	97·3	98·4	5406	1039	1016	81		9	8	82	15	
11	98	98·3	6000	1042	1015	84		9	8	86	15	
12	97·4	99	4400	1043	1015	61		9	7	80	16	
13		99	5802	1043	1016	81·2		9	7½	78	16	
14		98	5206	1044	1016	72·8	4 eggs, 1 lb. cold fat bacon, gluten bread, 1 pint beef-tea, watercresses for breakfast and tea.	9	5½	80	16	
15		98·3	4609	1042	1016	69		9	7	86	16	
16		99	5200	1041	1016	67·6		9	7	76	16	
17		98·1	3000	1042	1016	51		9	7½	84	16	Galvanism discontinued.
18	98	98	4604	1041	1016	60		9	7½	76	15	
19	98·2	99	4800	1041	1016	67·2		9	7	80	16	
20	98		4206	1037		63		9	7	82	14	
21			5200	1037	1014	72·8		9	6½	80	15	
22			4700	1040	1013	61·1		9	9	80	16	
23			4600	1039	1012	55·2				80	15	
24			1700	1040	1012	20·4				78	15	
25			2500	1040	1013	32·5				74	15	
26			2700	1038	1012	59·4				72	15	
27			4300	1037	1012					68	15	
28												

CHAPTER VII.

ELECTRICITY AS AN ANODYNE AND SEDATIVE.

PERHAPS it would have been more scientifically accurate not to have made a separate chapter for a discussion of the points to which the reader's attention is now to be directed. The power of the electric current over pain and spasm is probably due to its stimulating action, and, like alcohol, it not only has the power of quickening vital processes but also of alleviating many of the most troublesome symptoms of disease.

It is, however, more convenient and will probably be found more practically useful to consider this division of our subject separately.

Among the most valuable, most generally applicable, and most undoubted effects of electricity is its power of annulling *pain.* It would almost seem to be one of the most powerful anodynes which we possess, and its power in this respect is hardly as yet fully appreciated by the profession. In the out-patient room we have been accustomed for some time past to try the effect of the continuous current upon pain of all kinds, whether depending upon some obvious organic cause or upon causes not obvious. In many cases we have found that the pain has been *alleviated,* and in a large proportion of these it has been absolutely *cured.* In some instances, especially among the female hysterical class, the mere sight of the battery and the application of the sponge-holders to the suffering place, without any current at all, has had the desired effect; and we have not unfrequently been amused as well as instructed in watching the power of the imagination and emotions in diverting the mind from troubles real and fancied.

We may here remark that when one is using electricity for the treatment of pain and other subjective symptoms, it is often a good plan (and, indeed, should, we think, always be the rule) to begin with a mock application of it, and in this way we see how much of our result is due to the patient's imagination and how much is due to the electricity. If we could as readily test the actual efficacy of many other therapeutic agents which we employ, our knowledge of treatment and the effect of drugs would become more accurate than it is.

Electricity will often cure pain, and much more often will alleviate it: and as an alleviator of pain it is not open, if properly used, to the objections which are applicable to most other anodyne therapeutic agents. By teaching a patient what are the anodyne effects of morphia, chloral, Indian hemp, or alcohol, we may alleviate his sufferings, but only at the expense of his physical and moral well-being. Again, the after-effects of anodyne drugs are often only less disagreeable than the symptoms which they have removed. Electricity is not open to these objections, for, if it does no good, it does not, we believe, do any harm; and for this reason, if for no other, it deserves every trial as an anodyne. For a local pain, counter-irritation by means of a blister is often of great use; but there is this practical objection to the use of blisters, that if the pain return before the blistered surface has healed, we are debarred from making a second similar application to the same spot. Electricity is a counter-irritant, and a very powerful and quickly acting counter-irritant; but it is something more than this—it has undoubted specific effects upon painful nerves; and it is not open to the objection of other counter-irritants, for it will not cause depression and exhaustion, and, if used with due care, may be applied again and again to the same region of the body.

The reader must not misunderstand these remarks, which are not meant as a crusade against time-honoured and invaluable remedies, but merely as an incentive when he has (as in hospitals) the necessary apparatus at hand, to try the anodyne and counter-irritating effects of electricity.

All three forms of electricity are employed for the relief of pain, but the most generally useful for such purposes is undoubtedly galvanism.

Some writers, when dealing with the anodyne effects of the galvanic current, lay great stress upon always placing the *anode* upon the painful spot. It is always pleasant to be in accordance with physiological facts, and it would increase our knowledge if we could be sure that the pain of neuralgia were always due to an exaltation of physiological properties which could be subdued by the production of anelectrotonus. Neither of these facts is certain, and Meyer—certainly an authority—says that the positive pole is to be applied near the centre, and the negative (the cathode) on the painful spot. For our own part, we have employed galvanism with much success for the relief of pain, but without hitherto paying any attention either to the direction of the current or the position of the poles. There is no relation, etymological or otherwise, between *anode* and *anodyne.*

There are many cases of *neuralgia* on record which have resisted every known method of treatment, but have yielded after a few applications of the constant current. In employing the current for this purpose, the true *locus morbi,* if it can be made out, should be included between the poles. If there is tenderness over any of the vertebræ corresponding with the part of the cord from which the painful nerves arise, one of the rheophores should be placed at or a little above this spot. The other rheophore should be applied seriatim to the various 'painful spots' along the course of the nerve. In employing galvanism for neuralgia of the trigeminus, care must be taken—because of its effect upon the eyes—not to use too strong a current.

We should not be doing justice to our subject did we not place on record the very decided opinions expressed by the late Dr. Anstie on the electrical treatment of neuralgia. None who enjoyed the friendship of that distinguished physician will for a moment suspect that his opinions were hastily formed, and therefore it is that we have inserted some passages *verbatim* from his work, 'Neuralgia and its Counterfeits':—

'In the first place I have arrived at a decided conviction that faradic electricity is of no value in true neuralgia. . . . Very different is the verdict of experience as regards the effects of the constant current; here the results which I have obtained have been so remarkable that even now I should distrust their accuracy were it not that they are in accord with the general result which (among minor discrepancies) may be gathered, we may fairly say, from *all* the more important researches that have lately been carried out in Germany. The constant current, as I now estimate it, is a remedy for neuralgia unapproached in power by any other, save only blistering and hypodermic morphia, and even the latter is often surpassed by it in permanence of effect, while it is also applicable in not a few cases where blistering would be useless or worse. . . . Only such a current is to be employed as produces only a slight tingling, and (on prolonged application) a slight burning sensation, with a little reddening of the skin at the negative electrode. . . . The next maxim is that the application of the current should be made at regular intervals, and at least once daily; in most instances this is enough, but occasionally it will be found useful to operate twice in the day. . . . The length of sittings is a point as to which there is considerable difference of opinion between various authorities, but my own experience coincides with that of Eulenberg, that from five to ten, or at the utmost fifteen minutes is almost the range of time. Closely connected with the question of the length of sittings is that of the continuity with which the current is to be applied. I have seen the best results, on the whole, from passing a weak current without any breaks for about five minutes. But where there are several foci of intense pain, it will often be advisable to apply the current to each of these, successively, for three or four minutes.'

Dr. Anstie does not lay particular stress either on the position of the poles or the direction of the current, but thinks, with Benedict, that the *locus morbi* should always be included, if possible, by the poles. He rather, however, inclines to the method of placing the *positive* rheophore on the *points douloureux* when such exist, the *negative* being placed on the spine opposite the point of origin of the nerve.

'There are very considerable differences both as to the best manner of galvanisation, and also as to the chances of doing good with it, in the case of neuralgias of different nerves; and, on the whole, I find Eulenberg's conclusion on this matter very just. He indicates *sciatica* as the affection which is by far the most curable by the constant current. . . . On the other hand, he reports that *intercostal neuralgia* has never been materially benefited by galvanisation in his hands. With regard to ordinary *trigeminal neuralgias*, he speaks strongly of the current as a *palliative*, but very doubtfully of its power to *cure*, in genuine and severe cases. In *cervico-brachial neuralgia* he speaks of it as dividing with hypodermic morphia the whole field of useful treatment in the majority of cases. In *cervico-occipital neuralgia*, he says, it rarely does much good. . . . The remedy, like every other, will doubtless fail in a considerable number of those very bad cases which occur in the degenerative period of life; but if anyone desires to see the proof of the power it sometimes exerts, he should study the two most remarkable cases treated by Professor Niemeyer of Tübengen, and reported by Dr. Wiesner. The patients were respectively aged 64 and 74, and the duration of the neuralgia had been respectively five and twenty-nine years; in both, the pain was of the severest type, and in both the success was most striking. In one of them every possible variety of medication, and several distinct surgical operations for excision of portions of the affected nerve, had been quite vainly tried. The cases are altogether among the most interesting facts in therapeutics that have ever been recorded. . . . As a general rule neuralgia of the limbs requires to be treated with a more powerful current than neuralgia of the face. . . . Of electrical treatment in regular *angina pectoris* I have had no experience, and in one case of intercostal neuralgia, complicated with quasi-anginal attacks, in which I applied the constant current to the spine and the cardiac region, in the direction of the affected intercostal nerve, no effect was produced. I shall, however, mention the experience of Eulenberg, as he is a sober and dispassionate writer on the effects of electrical treatment in general. He says that in the proper use of the constant current we shall discover the chief, possibly the only direct, remedy for angina; and he describes the apparently favourable results he has already obtained in three or four cases. The current was from thirty cells; the positive pole was placed on the sternum (broad electrode), the negative on the lower cervical vertebræ. *Neuralgia of the testicle* can be best treated, if galvanism be thought necessary, by immersing the whole scrotum in a basin of salt and water, in which the positive pole is placed; the negative pole is to be placed on the upper lumbar vertebræ. . . . In *neuralgia of the urethra* I should be inclined to adopt a plan mentioned to me by Dr. Buzzard, of attaching one conductor to an ordinary silver catheter introduced into the urethra, and placing the other pole upon the perineum.'

The following case of *angina pectoris* occurred in the practice of Dr. Ralfe at the Seamen's Hospital, Greenwich, and is from notes supplied by Dr. Duncan :—

Case XIII.

Angina Pectoris.—P. M., æt. 42, admitted into Seamen's Hospital for angina pectoris, under Dr. Ralfe, Feb. 24, 1874.

History of Attack.—Four weeks before admission, whilst engaged at his work on board ship, had a sudden attack of acute pain, starting from the cardiac region and then coursing down the left arm as far as the fingers. This was accompanied by a feeling of great oppression in the chest. Has had three or four attacks since.

Present Condition.—Aged appearance; grey hairs plentiful; slight arcus senilis; pulse slow, weak, intermittent; enlarged area of cardiac dulness.

Was treated with spirits of chloroform and Hoffman's anodyne at first. Had several attacks of the pain.

The voltaic battery was then ordered, March 10. After the third application, patient felt much better, the pain being less severe. About thirty cells of Foveaux's battery were applied. Still better after fourth application.

The method of application was to place the negative pole to the nape of the neck, and the positive over the cardiac region and down the inner side of the arm. Dr. Ralfe, writing in reference to this patient, says: 'Not only is the pain less, but the general appearance has improved greatly; he looks less aged and anxious. The pulse, which at first was very irregular, is now steady, though feeble.'

The author has had one case of angina under his care, but the relief derived from the constant current was almost too slight to be appreciable.

Case XIV.

Cervico-brachial Neuralgia, treated by the Constant Current.—Dr. Buzzard communicated the following case to the Clinical Society on May 12, 1871.

Harriet P., æt. 65, first consulted Dr. Buzzard in January 1869. The facts in her constitutional and family history were of negative value. Five months previously she had been seized with giddiness, had fallen down, and lay on the floor several hours. A similar seizure followed a fortnight later, in which she lost consciousness, and, on regaining sensibility, found constant shaking of the right arm and leg, with thickness and indistinctness of speech, which was followed by giddiness and vomiting, &c. When Dr. Buzzard first saw her, her symptoms comprised cervico-brachial neuralgia of the right side, great photophobia, vertigo, and tinnitus aurium. Blistering and subcutaneous injection gave no relief, but some benefit was derived from a belladonna liniment applied to the right side of the occipital region. Her symptoms gradually subsided, and she went into the country in June 1869.

On December 27, 1870, Dr. Buzzard saw her again. She had then been suffering for three months. She complained of a fixed violent pain in the right arm, in the situation of the middle of the biceps muscle, and repeated and sudden daily and nightly 'paroxysms of agony' shooting up and down the arm. There was no wasting of the right arm, but its grasp was somewhat deficient. There was pain and tenderness over the shoulder joint and on the humerus. Her paroxysms averaged one an hour during the day, or five during the night. It would occupy too much of our space to give the details of the treatment, but the following summary by Dr. Buzzard is full of interest:—

'The patient, sixty-five years of age, is suffering from neuralgia of the cervical and brachial plexus of the right side, which is clearly of central origin. On sixteen occasions I applied the constant current between the cervical spines and the shoulder or hand. The result was great relief on ten occasions, moderate relief on two, and very slight relief on four. With a view of testing the treatment, I occasionally intermitted it and used other appliances with the following results. The process described as the galvanisation of the sympathetic, with the negative pole in the stylo-mastoid fossa, was followed on the one occasion on which it was used by great relief; with the positive pole in the stylo-mastoid fossa there was no abatement of pain. The constant current was once applied from the insertion of the deltoid to the hand; this produced no relief. I once injected concentrated extract of ergot without any result. The application of one blister was followed by considerable amelioration, but two others, which were applied in succession, produced no result. The use of iodide and bromide of potassium for two or three days was followed by decided comfort. Neither iron nor sedatives produced any mitigation of pain, but they upset her head. Faradism undoubtedly did her harm. The impression produced on my mind by the results of galvanism in this was a strongly favourable one, but it is of course difficult, in dealing with a subjective phenomenon like pain, to describe very clearly to others the grounds upon which such an impression is based. . . . The woman's manner when she had been spared the very terrible suffering with which she was at other times afflicted, spoke in a tone which is ill conveyed by such expressions as "great relief" or "moderate relief." I may add that the direction of the current did not appear in this case to be of importance. On several occasions I reversed the poles, so that sometimes a direct and sometimes an inverse current was employed.'

CASE XV.

Cervico-Brachial Neuralgia, apparently Cured by the Constant Current. (Dr. Anstie, Clin. Soc. Trans., vol. iv.)—M. T., a woman, æt. 48, applied to Dr. Anstie at the Westminster Hospital, in November 1870. About three weeks previously (having been overdone with household work and worry) she had been suddenly attacked with a paroxysm of pain on the right side of the neck, which with slight interruptions had continued. The pain of which she complained was centred in four different points: (1) at the lower and posterior part of the neck; (2) on the shoulder (corresponding to the emergence of the superficial filets of the circumflex nerve; (3) in the axilla; and (4) at the inferior angle of the scapula. There was well-marked anæsthesia of the cutaneous surface of the shoulder and the posterior part of the neck; and even in the absence of acute pain there was a weakness both of the deltoid and the trapezius which really amounted to partial paralysis. There were occasional fibrillary spasms to be noted in the deltoid. Quinine had given no relief; mustard plasters had afforded slight alleviation. For two months she received 'every possible medicinal treatment' at the hands of Dr. Anstie, and at the end of three months she was worse. She was then iodised with no benefit. At the beginning of March galvanism was tried—ten to fifteen cells of Weiss's battery; positive pole alternately over the foci of pain, negative (a broad moist sponge) on right side of lower cervical vertebræ. 'In the very first séance complete arrest of the pain occurred; and the next attack was less severe than usual.' At the end of sixteen days she had been free from pain for three days. At the twenty-fourth sitting she had not suffered for eleven days, the anæsthesia was gone, and the muscular power nearly restored. No recurrence had taken place six weeks later.

Case XVI.

Double Occipital Neuralgia, not Relieved by Electricity. (Dr. Anstie, Clin. Soc. Trans., vol. iv.)—'An unmarried, hard-working, respectable sempstress, æt. 30, has suffered for six months from double occipital neuralgia, bilateral pains (nearly equally severe on both sides) starting from the occipital triangles and radiating up the back of the head; there was a very painful focus over the point where each great occipital nerve becomes comparatively superficial. Internal remedies of every kind, blisters, hypodermic injections of morphia and atropia, as well as the constant current, all proved utterly inefficacious, and the actual cautery was used as a last resource, and with considerable success.'

Dr. Anstie makes the following remarks:—'Nothing is more striking and more direct, in the whole range of practical therapeutics, than the efficacy which the constant current shows in a large proportion of cases of neuralgic pain. In a not inconsiderable number of cases it cures absolutely, even when the most powerful remedies have failed; and in a far greater number it at least proves much the most efficacious palliative that we can employ. As a general rule, it may be said that there is the best chance of its succeeding in cases where the patient has not yet entered upon the stage of tissue degeneration which marks the later period of life. But now and then, from some reason which we are as yet altogether unable to explain, the current fails entirely, even in the case of a person who is as yet comparatively young. It is greatly to be desired that further investigations should be carried out, with unremitting diligence, until we can understand the reason of these puzzling and discouraging, though happily rare, failures of the constant current. . . . It is worth while to remember that cervico-occipital neuralgias, by the consent of the best authorities, are decidedly hard to cure by any treatment.'

In some cases of neuralgia the pain is much aggravated by using the muscles which derive their nervous supply from the painful nerve. In these cases it is well, when employing the current, to practise during its continuance a rhythmical exercise of the affected muscles. In this way the muscles, which have been thrown *hors de combat* by the pain, recover their tone, and it is only reasonable to suppose that the healthy exercise of the muscular and nervous function has a beneficial effect upon the healthy nutrition of the entire nerve, from its terminal twigs to its origin in the spinal cord.

The rational treatment of pain is, as with every other ailment, to remove the cause: and the complete and often immediate cure effected in some instances by electricity would seem to prove that the change produced in the nerves by the current is sufficient for this purpose. Many cases of neuralgia have been cured in this way at once. More than once we have completely removed a troublesome headache, not only of the transient type, but also of the migrainous periodic type, by a single application, for a few moments, of a weak current to the head. The pain under the left breast, so common in anæmic women, is often readily amenable to electrical treatment; and Dr. John Williams, of University College, tells us that he has often found ovarian pain yield to the application of galvanism. When, however, the cause is something evidently beyond the reach of electricity, we may nevertheless alleviate the pain for a time, often for many hours, by employing a galvanic current.

We record the following instance of a patient of Charing Cross Hospital who came suffering from 'lumbago.' That the 'lumbago' was possibly caused by serious mischief in the cord or its coverings was evident by the great tenderness of the spinal column, the sensation of numbness in the feet, and occasional attacks of spasmodic pain shooting into the lower limbs. Nevertheless he derived much benefit from the current.

CASE XVII.

'Lumbago' caused by Incipient Caries.—The patient was a poor basket-maker, and when first he came under observation he was scarcely able to move because of his pain. Counter-irritation and drugs having given him no relief, it was determined one day to try the effects of the galvanic current. He was then unable to walk, and was obliged to perform the journey to and from the hospital in an omnibus. The galvanic current was applied to the back, the pain was completely alleviated, and he was able to walk away with little or no difficulty to the nearest railway station, half a mile off. This alleviation lasted about twenty-four hours, when his troubles returned. After this upon several occasions he presented himself for the purpose of having the current applied to his back, for its application was always followed by many hours of freedom from pain, while nothing else seemed capable of giving him relief. We then lost sight of him for six months, when he again presented himself in the out-patient room, with a large lumbar abscess and every sign of caries of the vertebræ, and he was admitted to the hospital to be under the care of the surgeons. We mention this case merely as an

illustration of the power of the current to alleviate pain, notwithstanding that such pain may be caused by the gravest, most permanent, and incurable organic changes.

CASE XVIII.

Occipito-Cervical Neuralgia caused by Disease of the Vertebræ.—Another instance no less remarkable was in the case of a middle-aged lady who was sent to the author by the late Dr. Anstie. For more than a year she had been a martyr to occipito-cervical neuralgia of the left side, of a most excruciating character. An examination of the left side of the occiput and neck revealed slight swelling, and, on deep palpation, a crackling sensation could be felt in the region of the transverse processes of the first two or three vertebræ. Whether this was due to rheumatic inflammation or caries one could not determine, but doubtless this mischief, whatever it was, was the cause of her trouble, and the patient was accordingly informed that galvanism would probably do nothing for her. Her pains were much aggravated when the trapezius or the rotators of the head were moved. The current was employed about half-a-dozen times, the positive pole being placed at the occiput, and the negative moved in a labile fashion over the side of the neck and shoulder. The muscles were rhythmically exercised at the same time. Whenever the current was employed her pain was alleviated, the alleviation lasting for varying periods. On one occasion she was free from pain for nearly two days—a blessing which she had not enjoyed for months. Of course she was not *cured*, and she is possibly now as bad as ever; but it surprised us not a little to find that, in the face of a grave permanent cause, we could give so much *alleviation.*

We have occasionally employed the current to alleviate the pains of intestinal colic, and often, though not always, with success, which in some cases was complete. We have, on the other hand, found many cases of pain in which the current apparently did no good whatever.

The galvanic current is, on the whole, the best for relieving pain, because it is itself the least painful form of electricity. Some writers—Meyer amongst them—strongly recommend faradisation, applied by means of a metallic brush or in the form of the 'electric moxa' to the painful spot. Dr. Tibbits records a case of sciatica which was cured by franklinisation, and also a case of facial neuralgia cured in the same way. The method employed was to 'charge' the patient, and then to 'take sparks' along the course of the affected nerves.

There is a class of painful and sometimes semi-paralytic affections the pathology of which is shrouded beneath that most connotative word '*rheumatic.*' The ordinary 'stiff neck' is one of these. A man sits or sleeps in a draught with his neck in a strained position, and the next morning he cannot move his head without suffering agonies of pain. Again, a coachman, exposed to all weathers on his box, finds that the deltoid muscle of his left (the driving) arm, from exposure to wind and damp, and from being kept in one position, refuses its office; he is unable to raise his elbow, and the attempt to do so causes him much pain. The stiffness felt in the adductors of the thighs after a long ride in the wet, and the pain and stiffness about the region of the right shoulder, which torment old sportsmen who have used the gun too much, belong to the same order of ailments.

Again, there are those various conditions which cause the symptoms of true 'lumbago,' situated at one time, we suppose, in the muscles of the back, and another time in the thick aponeuroses which cover them. Sciatica is another of the 'rheumatic' ailments, the characteristics of which occasionally are that the pains do not follow the lines of nerve distribution very exactly, and that the pain is as much 'muscular' as 'nervous' in character, and is much aggravated by muscular movements.

Now in the vast majority of these cases it will be found that faradism and galvanism, but especially the latter, act in a way which is little short of magical. If we were asked to state for what class of diseases electricity was of the greatest use, we should have little hesitation in saying the class which we are now discussing. We believe it to be essential that the painful muscles should be made to contract thoroughly. This may either be done by employing faradism and so causing a strong artificial contraction, or we may use the constant current, and while the patient is under its anodyne effects, make him thoroughly exercise all the muscles implicated.

Not long ago the coachman of an eminent London surgeon came to the author complaining of the 'rheumatism' of his left shoulder. On examining him, it was found that his left deltoid muscle was almost useless to him. He could not, and had not, he said, for many years been able to raise his elbow except in a very slight degree, and always with pain. He had exhausted the various liniments and oils, but with no benefit. We strongly faradised his deltoid muscle, and in a few minutes he was able to raise his elbow quickly and repeatedly above the level of his shoulder. Cases are not uncommon in which a cure may be effected quite as quickly and completely.

A very obstinate case of 'lumbago' was put under the author's care in Charing Cross Hospital by his friend and then colleague, Dr. Julius Pollock; and as it shows very strongly what electricity will do in such cases, the facts are appended.

Case XIX.

'Lumbago' of six years' standing.—W. G., a brass-finisher, aged thirty-five, was admitted as an out-patient on July 16, 1873. He was bent almost double, walked with the greatest difficulty, complained of intense 'lumbago' pain, and gave the following history:—He had been accustomed to work a good deal with the lathe, standing up and moving the treadle with his right foot. About six years ago a pain came on gradually, affect-

ing the back of the thighs and hips, which the medical man attending him called sciatica. The pain became so severe that he was obliged to give up work, and had not since been able to resume his employment. The pain left his legs, and finally settled in his back; it was most marked in the lower dorsal and lumbar regions, and was of a plunging, shooting character, aggravated by the slightest movement or the lightest touch, and implicating not only the dorsal muscles, but the intercostals as well. Movement had become so difficult that he was often as much as two or three hours in dressing and undressing himself. The back was considerably 'bowed,' the curvature being far more noticeable at night than in the morning. There was no indication whatever of any disease of the vertebræ, and the ailment seemed to be mainly muscular.

The positive pole was placed at the upper part of the spinal column, in the middle line; and the lower part of the back, and the lateral regions of the thorax were thoroughly sponged with the negative pole. The sponging had the immediate effect of annulling his pain, and produced great redness of the skin of the back and chest. While the current was being used he was made to exercise his muscles, to flex and extend his back, to rotate his spine, and to inspire and expire rhythmically and repeatedly. The result of this treatment was his rapid improvement, and he was soon enabled to resume his employment, which he had discontinued for six years.

CASE XX.

Tinnitus Aurium.—The following is an instance of relief afforded to a troublesome condition.

The patient was a middle-aged man, and when he applied for relief among the out-patients of Charing Cross Hospital he was suffering, and had suffered for nine months, from that most troublesome annoyance *Tinnitus Aurium.* There was, he said, a noise 'like the blowing-off of steam' constantly going on in his left ear. The least jarring of his body, even when walking, was most painful to him, and the roar of the London streets had become intolerable. We will not hazard any opinion as to the pathology of this disease; but it will, perhaps, suffice to say that a careful examination of the ear revealed to us nothing physically wrong with it, and that the clearing of the ears of wax, and the employment of nervine tonics and nervine sedatives had proved of no use. We then thought of giving galvanism a trial, and putting one rheophore in the patient's hand, we applied the other to the meatus of the affected ear. He was immediately relieved; and at his next visit, a week later, he stated that he had been free from the noise for five days, and it then returned again, but not so severely. We repeated the application, and the result has been that he has almost entirely lost his trouble.

Electricity is no panacea, and often fails entirely to relieve pain, although we believe that on the whole the cases in which it is effectual would outnumber those in which it fails. Unfortunately, we are unable to give any rules which should lead us to expect either failure or success in any particular case. As our knowledge increases, our powers of prognosis will doubtless increase also.

In cases where the functions of the brain are deranged, galvanism has been of service.

The power of the galvanic current (when applied to the head) over most of the ordinary forms of headache is a matter on which the author has no doubt, but he has had no experience of its efficacy in the graver disorders of the brain. It is stated to act as a powerful calming agent during periods of excitement, and to serve as a valuable hypnotic in cases where wakefulness arises from no obvious organic lesions.

In cases of functional brain disorder we should feel very much inclined to try the effects of the galvanic current. One need hardly repeat the caution which has been before uttered, that the mildest currents must be used at first, and that their increase should be very gradual and their effect most carefully watched.

Galvanism has been employed, and it is said with success, in the treatment of *Exophthalmic Goitre*, or Graves's disease. The method pursued is to pass a mild continuous current across the course of the cervical sympathetic. The author has tried its effect on one such case, but neither the pulse-rate, the protrusion of the eyes, nor the enlargement of the thyroid gland were appreciably influenced. The symptoms improved, however, with small doses of digitalis.

Dr. M. Meyer (Berliner Klinische Wochenschrift, No. 39, 1872) records four cases of this disease which were most successfully treated by the application of the galvanic current to the cervical sympathetic.

The treatment of *Spasmodic Diseases* by electricity is not in high favour, and, as a rule, but small success has followed its employment. We believe, however, that in a certain proportion of spasmodic affections electricity is capable of giving relief; and we shall endeavour to point out how to bring about that desired end. It will be necessary for us, at starting, to look at the broad features of the subject, and endeavour to effect some classification of spasm which may be of use to us in indicating the suitable therapeutic measures.

What, then, are the varieties of spasms? Writers are accustomed to speak of 'clonic spasms,' or spasms of momentary duration; and of 'tonic spasms,' or spasms of prolonged duration. A spasm we must define as an involuntary and irregular contraction of a muscle. Convulsions are attacks of spasm both clonic and tonic, affecting the whole or considerable districts of the body; and it will, perhaps, clear the ground a little if we say that there is no good evidence to show that electricity has ever been of the slightest use in relieving general convulsive seizures, whether dependent on 'teething,' epilepsy, tetanus, uræmia, the puerperal state, or intracranial mischief. It does not seem rational to expect that electricity could be of any service in such cases.

Clonic spasms are general or local. Chorea is a disease which is characterised by general clonic spasm.

Of localised clonic spasms we have familiar examples in stammering (which is presumably due to clonic spasm of some of the muscles used in vocalisation), and hiccuping (which is due to clonic spasm of the diaphragm). The former of these troubles is not difficult to cure, or rather to avoid, by attention to pitch and rhythm in speaking, and we are not aware of any evidence as to the beneficial effects of electricity, although it has been employed. Satisfactory evidence as to the beneficial effect of any remedy in stammering is difficult to obtain, because even the very worst stammerers can, as a rule, obtain a certain mastery over their ailment, and it is impossible to determine whether or no improvement is due to remedial agents, or to strength of will.

Another form of clonic spasm is that which affects the muscles of the face. This is seen in its mildest form in that little quivering of the lower fibres of the orbicularis palpebrarum which patients sometimes speak of as 'live blood,' and which is dependent apparently on a disordered stomach. Possibly the very delicate structure of this muscle makes it particularly susceptible of reflex irritation. In an aggravated form this clonic spasm attacks the whole of the muscles supplied by the facial nerve, and it is then called the 'histrionic spasm.' It sometimes depends on reflex causes, and has been attributed to morbid conditions of some of the branches of the trigeminal nerve. More often it is due to direct irritation of the facial nerve itself. Two cases we have lately seen in the out-patient room were almost certainly due to a morbid condition of the facial, for in one of them it was accompanied by disturbance of hearing, and a discharge from the ear, and in the other there was distinct tenderness behind the jaw, and the patient stated that the act of eating, which presumably caused some mechanical disturbance of his nerve-trunk, invariably aggravated his troubles. In neither of these cases was electricity in any form of the least use, although they both yielded to large doses of bromide of potassium.

Another form of local clonic spasm is that painful twitching of the stumps of limbs which sometimes occurs after amputation, and which is often accompanied by a bulbous condition of the nerves. We have tried the effect of the continuous current in one such case, and without the least success. Not the least alleviation of either pain or spasm occurred.

Another variety of clonic spasm is *tremor.* Now tremor may depend on many causes. Emotional causes, such as rage or fear, will cause trembling of the muscles. The reason for this would seem to be that the mental power, being in great part devoted to the emotions, is insufficient to control the muscles. For the healthy physiological action of a healthy muscle a certain definite quantity of stimulation would seem to be necessary. If the stimulus is not forthcoming, we get paralysis. If it is insufficient in quantity, owing to emotional diversion or impairment of conducting power in the spinal cord or nerves, we get tremor. The want of conducting power in the cord or nerves may be due to permanent causes, such as senile degeneration, or to removable causes, such as alcoholic or mercurial poisoning. In cases of *paralysis agitans* occurring in old people it is rare to find improvement take place, although Dr. Reynolds has recorded a case which was relieved by wearing a Pulvermacher's chain. If the cause of tremor is an immovable lesion, it is of course idle to expect improvement by mere treatment of the symptoms. In cases of mercurial tremor we should be strongly inclined to recommend faradisation of the muscles, because the thorough contraction of the muscles thus brought about would certainly help to eliminate the poison from the damaged tissue. Faradism has, in fact, been of great service in such cases. In mercurial tremor the muscular tissue presumably suffers as well as the nervous tissue; but owing to the impossibility of separating the muscle from the nervous twigs which ramify in it, it is impossible to say which is at fault.

In certain morbid conditions of the muscle—as, for example, the granulo-fatty degeneration which takes place in progressive muscular atrophy—it is common to observe a fibrillary tremor of the muscle which occurs wholly independently of volition. This fibrillary tremor can, according to Duchenne, be arrested by systematic faradisation of the muscle at fault, thus bringing about a more active nutrition of it, but in the author's experience continuous galvanisation is of more decided service.

Another common cause of tremor is *Exhaustion.* It must have been a not uncommon experience of all of us that after severe and unwonted muscular effort general tremor of the muscles has set in, a tremor which, for the time being, gives an uncertainty to all muscular movements, and makes us conscious of a peculiar jerking of the muscles throughout the body. This tremor is probably due partly to the exhaustion for the time being of the muscular tissue, partly to the exhaustion of the voluntary stimulus, and possibly the lines of conduction may have become exhausted also. This tremor may be called the tremor of acute fatigue.

Since *Fatigue* is by no means an uncommon cause of disease it will be well in this place to make some general remarks on the subject, and especially because the author believes that electricity will be found of more genuine service, perhaps, in '*fatigue diseases*' than in any other class of maladies.

Work results in fatigue, and fatigue is a regular and constantly returning symptom experienced by all of us. Periods of functional activity invariably alternate with periods of repose, during which the waste caused by the exercise of function is repaired. We are indebted to Sir James Paget for having pointed out in his Croonian Lecture, delivered some years since before the Royal Society, that 'rhythmic nutrition' is a law of nature; but, although the truth of this dogma is recognised on all hands, and may be said to be axiomatic, it has hardly received that careful consideration at the hands of practical physicians which it deserves.

Our whole life consists of a series of vibrations—periods of tension alternating with periods of relaxation; and, although the rapidity of these vibrations varies immensely, they are recognisable in all our acts, be they voluntary or involuntary. Let us look first to the 'vibrations' of an organ the movements of which are placed entirely beyond our own control—the heart. Now, the rate of vibration of the heart is 72 per minute, and if the total period of each vibration be divided into ten parts, it will be found that four of these parts are devoted to the process known as *systole*, which may be looked upon as labour; three are occupied by the *diastole*, which, although hardly labour, is nevertheless exercise of function; and the remaining three parts are occupied by the *pause*, during which the heart apparently enjoys absolute rest from any exercise of function, and may be considered to be in a condition analogous to sleep. May we not apply the rate of action of this organ, which has been regulated for us, to our voluntary acts, and may not the heart be made to give the key-note, as it were, to many questions, personal and social? If we divide the day of twenty-four hours into ten equal parts, and give four of these to active work, three to functional exercise of other kinds, and three to sleep, we shall find that nine and a half hours' work, seven and a quarter hours' 'relaxation,' and seven and a quarter hours' sleep, is what a normal man may, and, as a rule, does perform without injury to himself.

To continue with the consideration of our 'vital vibrations,' we may remark that it is universally ordained among civilised nations that once in every seven days there shall be a remission of labour and a change of occupation; and we further recognise the fact that it is highly advisable for those who are occupied in monotonous pursuits to break away from them at least once a year, and indulge in that variety of work which we call amusement. Monotonous repetitions of the same act are acknowledged, on all hands, to be the most potent causes of fatigue.

Fatigue occurs directly we attempt to alter the rhythm of our vital vibrations by prolonging the periods of tension at the expense of the periods of relaxation, or by demanding for any length of time a quickening of the normal rate of vibration; and it is not unreasonable to suppose that every organ of the body has its 'normal rate of vibration,' if we could only determine what it is.

We recognise the fact that athletes who 'over-train' run risks of cardiac troubles and loss of wind; that the man who from any cause is unable to sleep runs a serious risk of permanent impairment of health; and when we find patients pursuing their avocations too zealously we know that, if such offence against the laws of nature be persisted in, general paralysis or other form of 'break-down' is likely to be the result.

Fatigue may be general or local, and both forms may be either acute or chronic.

That fatigue in all its forms is due to impaired nutrition there can be little doubt, and we shall find that the symptoms of chronic fatigue are often the prelude of definite and recognisable degenerative changes.

As to *general fatigue*, it is recognisable with care both in its acute and chronic forms. There is a disability for performing either mental or physical work, and this disability is noticed first in work requiring attention and sustained effort, and, lastly, in those acts which have become automatic The symptoms of general fatigue are referable usually to the brain and nervous system.

As to *local fatigue*, this, again, may be acute or chronic, and the symptoms of it are referable usually to the muscles; but we must always bear in mind that muscle and motor-nerve are one and indivisible, and that recent experiments have given great probability to the idea that every muscle is connected with a certain definite spot in the brain. When, therefore, we speak of a sense of fatigue we must necessarily be in doubt, notwithstanding the fact that the symptoms are referred to the muscle, whether brain, nerve, or muscle, one or all of them, be really at fault. The symptoms of acute local fatigue are (1) *loss of power* to a greater or less extent. By too frequent or too prolonged stimulation the irritability of muscular tissue becomes exhausted, and it either refuses to respond or responds but feebly to the stimulus of the will; our power of adjusting the force of contraction to the act to be accomplished is lessened, and accuracy of movement and delicacy of co-ordination become impossible. (2) *Tremor* is a symptom of acute local fatigue, which everyone who has been called upon for extraordinary muscular effort must have experienced. (3) *Cramp-like* contraction is the symptom of local fatigue which disturbs our rest after a hard day's walking or riding, or muscular efforts in the ball-room or elsewhere. (4) The *pain* of fatigue is familiar to most of us, and is readily distinguishable from other forms of pain.

Local fatigue is caused far sooner by prolonged and sustained muscular effort than by repetitions of short muscular efforts having due intervals of relaxation between them. Anyone who has attempted to hold out a weight at arm's-length knows the impossibility of a long continuance of the effort, and it is proverbially true that standing in one position is to most people far more tiring than walking, the reason apparently being that in standing the muscles which support the body are subjected to a prolonged strain, while in walking we use the muscles on either side of the body alternately. The great increase of working power which we obtain by this alternating use of the muscles would seem to be one of the chief reasons for the bilateral symmetry of the body. Not only is sustained effort a far more potent cause of fatigue than repeated effort, but we find that, when fatigue supervenes, actions requiring sustained effort, be they physical or mental, are the first to fail, while automatic actions endure the longest, and in this respect local fatigue resembles general fatigue. It is quite possible to exhaust a muscle by artificial stimulation, and if one of the small interossei muscles of the hand be continuously faradised, it will be found, as before stated, that in a short time its power of contracting under any form of stimulus will be absolutely abolished. It is tolerably certain that the brain can have no share in artificial fatigue thus produced, and there seems good reason to suppose that in some people of energetic temperament the irritability of a muscle may be exhausted while the power of mental stimulation remains unimpaired. Although the author dwells chiefly on the peripheral phenomena of fatigue, he readily admits that these must be generally accompanied by central changes. What these latter are must remain a matter of speculation, but in the peripheral phenomena we have something recognisable and certain, and deserving of our most careful attention.

Chronic local fatigue has causes and symptoms similar to those of acute local fatigue, and there can be little doubt that this condition is a common cause of many of those chronic maladies which seem to result from overwork, and which are characterised by irregular muscular action. That some cases of writer's cramp, torticollis, and hammer-palsy, are due to chronic fatigue of the muscles employed, there can be little doubt. Duchenne and Mr. Brudenell Carter have pointed out how, in cases of short sight, the prolonged strain of the internal recti has caused troubles of vision and even cerebral symptoms; and quite lately Dr. C. B. Taylor, of Nottingham, has shown reason for including in the category of 'fatigue diseases' a peculiar form of nystagmus occurring amongst miners, who try their eyes by working in the dark, and the author has little doubt that, attention having been directed to the symptoms and effects of fatigue, additional light on the subject will be forthcoming.

For the better understanding of this subject of 'chronic fatigue,' which we believe plays no unimportant part in many morbid conditions, we may pass on to the consideration of that condition in which the author has chiefly studied it—viz., *Writer's Cramp.* Writer's cramp or scrivener's palsy is one of those diseases which Duchenne calls 'functional impotences,' and it is stated in text-books that the disease is characterised by inability to perform the act of writing; that all other acts, however delicate, are performed perfectly well, but that immediately the patient attempts to write he fails (either at once or after having written a few words), generally by the pen eluding his grasp, or sometimes by tremblings of the fingers, or definite objective spasm of some of the muscles employed in the act of writing. The pathology of this disease has been stated to be a 'derangement of co-ordinative centres.'

Duchenne[1] is of opinion, and mainly, it would seem, because the disease is uninfluenced by localised faradisation, that functional spasm or impotence is due to a lesion of some point of the *nervous centres.* He is confirmed in his opinion because the left hand, in cases of writer's cramp, is as liable to suffer (should it be used for writing) as was the right one. 'Do not these facts,' he says, 'tend to show that voluntary stimulation, often repeated by such and such functions, has not only produced at length a morbid condition in a given point of the spinal cord, but that it has extended its action to a neighbouring point on the opposite side?'

He says, further: 'One must also admit for the development of this malady, as for all others, a particular predisposition. In point of fact, numbers of people abuse the functions of writing without being afflicted by writer's cramp.'

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[1] *De l'Électrisation Localisée,* 3rd edit. pp. 1021 *et seq.*

The late Mr. Solly[1] was of opinion that the cause of writer's cramp was a granular disintegration of the cervical portion of the spinal cord.

Dr. Reynolds,[2] after pointing out that for the production of a complicated movement, such as writing, the integrity of a great number of parts is necessary—the will, motor and sensory nerve-fibres, certain ganglia situate upon the nerve-trunks, the cerebellum, the muscles, and the special senses—goes on to say that in the disease in question 'it cannot be doubted that some changes take place in the nutrition of the parts through which the lines of nerve action, regulating the secondarily automatic movements, run. It seems probable that the association of movement is effected by ganglia, which are common to fibres passing through distinct but contiguous nerve-trunks, and that it is owing to some nutrition change in them—the result of persevering and forced effort—that the perfection of movement is produced; associations at first caused by the will are at length produced unconsciously. What happens, then, in such maladies as writer's cramp is a perverted nutrition of these parts; a worn-out activity, or a degeneration which may arise without over-exertion and destroy all that has been previously achieved.'

Dr. Julius Althaus[3] is 'inclined to look upon scrivener's palsy as a symptom of fatigue and functional irritability of the co-ordinative centres in the upper portion of the spinal axis which have by education been trained for the guidance of the mechanical act of writing.'

Professor Niemeyer[4] remarks that 'we know nothing positive as to the pathogeny of the disease.'

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[1] *Lancet*, vol. i. 1865.

[2] Reynolds' *System of Medicine*, 1st edit. vol. ii. art. 'Writer's Cramp.'

[3] *Scrivener's Palsy*. A pamphlet. 1870.

[4] *Text-book of Practical Medicine* (Eng. trans.), vol. ii. p. 320.

Dr. Crisanto Zuradelli,[1] of Pavia, who has published two valuable papers, 'Del Crampo degli Scrittori,' holds that 'these perversions of functions are not true spasms, but are due to paralysis of one or other of the muscles used in writing, in consequence of which the antagonising muscles get the mastery and occasion a spurious cramp.' He points out that the paralyses present are not paralyses in the ordinary sense of the word, but are comparable to that condition which other physicians have alluded to as '*irritable weaknesses.*' He shows that writing consists of *three* separate acts: (1) the stroke-making movement of the pen; (2) the movements of the hand from left to right; and (3) the movements which take the hand to the ink-pot: and when any one of the muscles by which one or other of these movements is effected becomes the seat of paralysis or irritable weakness, we get a variety of 'Writer's Cramp.' In the chief form the weakness lies in the thumb and fingers; but he remarks that the paralysis sometimes spreads to muscles which are not used in writing, and that in progressive cases the muscles are affected in the following order: hand, fore-arm, arm, shoulder. The affected muscles have diminished tonicity and electric irritability, and their employment causes intense feeling of fatigue. Dr. Zuradelli says that scarcely any two cases of writer's cramp resemble each other, a remark the truth of which all who have seen much of the disease will confirm.

Geigel,[2] Haupt,[3] and Meyer[4] have all published papers on writer's cramp which go to confirm the theories put forward by Zuradelli.

The foregoing theories are divisible into two classes. In the first class, the lesion causing writer's cramp is referred to the nervous centres; in the second class, the parts at fault are alleged to be the muscles themselves.

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[1] *Gaz. Med. Ital. Lombardia,* No. 36–42, 1857; and *Annali Universali,* 1864.'

[2] 'Der Schreibekrampf und die functionellen Krämpfe und Lähmungen,' *Wurzburg. Med. Zeitschrift,* 1864.

[3] *Ueber den Schreibekrampf,* &c. Wiesbaden, 1860.

[4] 'Zur Therapie des Schreibekrampfes,' *Verhandlung der Berliner Aerztliche Gesellschaft,* 1868.

Assuming the first class of theories to be correct, one cannot help asking this question:—Supposing a man with uncomplicated writer's cramp to be killed suddenly by an accident, where would one expect to find the exact anatomical seat of the morbid changes? The number of automatic and secondarily automatic complicated movements of which we are capable must be almost innumerable (only limited possibly by the commutations and permutations of which the whole number of human muscles is capable), and the educated regulating centres of such movements must be innumerable also. Of all the secondarily automatic complicated movements which we are capable of acquiring, the one which is most commonly affected by the disease in question is that of *writing*. Among the whole range of functional spasms and functional palsies, writer's cramp takes the pre-eminence. Its occurrence is infinitely more common than that of *sempstress's cramp*, *milker's cramp*, *cobbler's cramp*, and the other rare varieties which have been occasionally described, notwithstanding the fact that the number of sempstresses, milkmaids, tailors, and cobblers cannot be very far short of the number of scriveners. There are numbers of secondarily automatic acquired complicated movements—such, for instance, as dancing—which are hardly ever overcome or rendered impossible by the occurrence of functional spasm or impotence, notwithstanding that each of these movements has presumably its regulating centre, which is as capable of degeneration and morbid change as is that regulating centre which is supposed to control the act of writing.

Now all who have any knowledge of this disease are aware that although the word *cramp* has been applied to it, yet actual cramps or spasms of any of the muscles concerned are often not evident even on the most careful examination; and that although the word *palsy* has been used, yet actual paralysis of any nerve, muscle, or group of muscles is only present as an occasional complication, and when present generally warrants us in placing the case in a category other than that of functional spasms. The person affected with *writer's cramp* in its fully developed form is able to make scarcely a line upon paper; directly he attempts to do so the fingers and thumb, one or other, become obstinate, and move in an irregular, unsettled manner, the result of which is that the pen is often twisted out of the hand, and the closest scrutiny of the hand and arm will often not enable us to say why. There is an 'impotence,' as Duchenne says, to write; and this word, which commits us to no theory either of spasm or paralysis, seems to be the best. Another important fact about writer's cramp is the progressive nature of the disease. At first the fingers alone may be affected, and the patient adopts some new mode of holding his pen which relieves him for a time; then possibly the whole hand becomes as obstinate as were his fingers, and ultimately the patient is obliged to resort to some mechanical means of fixing the pen to the wrist or fore-arm—a plan which may serve him for a time, but sooner or later (if he persevere in writing) the muscles of the fore-arm, arm, and shoulder become as obstinate and troublesome as were those of the fingers in the first instance. In fact, the disease might be called '*progressive functional ataxy.*'

Professor Zuradelli, as quoted above, has pointed out that writing is a complicated act; but he has not gone quite far enough in his analysis of the muscular actions required for writing, and that which is certainly of the most vital importance, and which in our opinion constitutes the very essence of the pathology, seems to have escaped his observation.

The act of writing is primarily divisible into (1) *the act of prehension*, and (2) the act of moving the pen; and the act of movement may be again subdivided into (*a*) the stroke-making movement; (*b*) the movement of the hand from left to right; (*c*) from right to left; and lastly (*d*) the ink-dipping movement. Besides the act of prehension, there is (3) another muscular act which Zuradelli does not mention: this is the poising of the fore-arm and hand, which is ordinarily kept about three-quarters prone, the hand being balanced upon the pisiform bone and little finger. Thus it will be seen that writing is divisible into three acts—the *prehension of the pen*, *the poising of the hand* and *fore-arm*, and the *movement of the pen*, and there is probably no muscle between the shoulder and the fingers which is not brought frequently into action during writing.

The muscular action to which we wish to direct very particular attention is that of prehension. The pen is normally held between the thumb and the first two fingers. The thumb and the index finger form an oval ring through which the pen-holder passes, being held by the distal and resting on the proximal end of the said oval. The distal ends of the metacarpal bones of the thumb and index fingers are widely separated; the first phalanx of the thumb is abducted; the phalangeal joint forms an angle which is more or less acute in different writers; and the pulps of the terminal phalanges of the thumb and index finger are, but for the intervention of the pen, almost directly opposed to each other. With regard to the first two fingers, the proximal phalanges are flexed, and the two terminal phalanges nearly straight. The muscles which keep the thumb and fingers in this attitude of prehension are, we believe, with one exception, *intrinsic muscles of the hand*, in proof of which, if the rheophores of a faradising apparatus with big sponges be placed, the one on the palmar surface of the hand between the thumb and index fingers, and the other on the dorsal surface over the metacarpal bone of the index finger (so as to influence more or less the special muscles of the thumb and first two fingers), the thumb and first two fingers will assume an attitude of pen-prehension (saving only the flexing of the phalangeal joint of the thumb), and a pen held between them will be tightly grasped.

The muscles chiefly concerned in the muscular act are, we believe, as follows:—The *interossei* of the first two fingers, which flex their respective first phalanges (the dorsal muscles further helping the act of prehension by dragging the first two fingers towards the thumb); the *abductor pollicis*, which abducts the first phalanx of the thumb, an action without which proper opposition of the pulps of the thumb and index finger would be impossible. The *opponens pollicis* and *flexor brevis pollicis*, as their names indicate, are also important muscles in the act of prehension. The phalangeal angle of the thumb is maintained, in a great measure, if not entirely, by the action of the *extensor primi internodii pollicis.*

The muscular effort of *poising the hand* is thrown chiefly on the supinators. The hand is three-quarters prone, and in this position the weight of the hand tends to make pronation complete — a tendency which is checked by the supinator longus, the supinator brevis, and possibly the extensors of the thumb.

The stroke-making movements are accomplished by the long flexor of the thumb, and the extensor secundi internodii, the flexor profundus digitorum, and the extensor communis digitorum. The up-strokes are in part dependent on an increased action of the interossei.

The movement of the arm from left to right depends chiefly on the triceps extensor, and that from right to left on the pectoralis. The muscles concerned in the ink-dipping movement scarcely require naming.

The five muscular acts above enumerated which taken together produce the complicated act of writing, are divisible into two classes. *In the first class (consisting of the prehension of the pen and the poising of the hand) the muscles concerned are subjected to prolonged strain, and (especially those concerned in prehension) are kept in a continuous state of contraction often for inordinately long periods.* In the second class of muscular acts the contractions of the muscles alternate with periods of repose.

Now, as long as a muscle remains contracted it is in a state of exercise, a condition which is 'attended with impairment of composition, such as can be repaired only during repose.' The muscles by which the prehension of the pen is effected need not of necessity obtain any interval of rest for hours together. During all the several acts which constitute writing, these muscles remain in a state of contraction; for the pen, in stroke-making, in horizontal movement, and in ink-dipping, cannot be released from the grasp of the fingers and thumb.

These muscles, whose function has been thus abused, soon begin to respond but sluggishly, or refuse entirely to respond to the stimulus of the will, and the scrivener finds that his grasp of the pen is faltering and uncertain. He finds that he is obliged to take a tighter grasp of the pen and (unconsciously, of course, as far as he is concerned) he deposes the proper muscles of prehension and substitutes others to perform their office. He begins to grasp the pen, not with the intrinsic muscles of the thumb and first two fingers, but uses for that purpose the big flexors of the thumb and fingers situated in the fore-arm. The *flexor longus pollicis*, the *flexor sublimis digitorum*, and the *flexor profundus digitorum* are now the muscles of pen-prehension, and the stroke-making movements of the pen are accomplished by the flexors and extensors of the wrist, or the writer finds himself incapable of resting his wrist upon the desk, because the movements of the pen have to be accomplished by the movement of the entire fore-arm by the muscles of the shoulder (the fore-arm being kept by means of its flexors at right angles to the arm). These new muscles of pen-prehension are kept in a condition of prolonged contraction just as were their predecessors, and in time become similarly sluggish, obstinate, and irritably weak, and the scrivener has to resort to new methods of pen-prehension, which generally consist of some mechanical contrivance, either entirely artificial or such as interlacing the pen amongst the fingers. The flexors of the elbow-joint (should they be used) soon strike work from a similar cause, and the triceps extensor is brought into use. The man writes with the pen mechanically fixed in the hand and the arm rigidly extended; the stroke-making action being accomplished by the movement of the entire body.

Other muscles which are very prone to suffer in writer's cramp are those which poise the hand, and which, like those of pen-prehension, are subjected to prolonged strain. It is a common observation that the poising muscles suffer in writer's cramp, and the hand is very liable to roll over in the direction of pronation (owing probably to the weakness of the supinators), or more rarely to be jerked in the direction of supination (as in a case recorded by Dr. Buzzard[1]) by the irritability of those same muscles. Many persons affected with writer's cramp become unable to poise the hand, and are obliged to write with the entire fore-arm supported and the hand in a state of complete pronation.

To illustrate our meaning we have purposely supposed an extreme case The disease, not unfrequently, does not spread beyond the fingers, but its rapid progression as depicted above is occasionally observed. When once the disease has commenced (showing itself perhaps merely as a trifling awkwardness in writing), its progress is liable to be very rapid if writing be persevered in. If, on the other hand, writing be abandoned on the first appearance of awkwardness, and the patient is able to give himself rest while his exhausted muscles of pen-prehension recover their tone, he rapidly regains his lost power.

Further, as to the act of writing, it must be borne in mind that it is one of the most complicated possible, perhaps the most complicated muscular act which is ever performed by the body. The act of writing takes years of patient labour to acquire, and although children begin to learn very early in life, it is seldom before adult age is reached that their writing loses those evident marks of juvenility which we all know how to recognise. Perfect writing should be an act accomplished without effort, and almost without thought, or, in other words, it should be a purely automatic act, and one accomplished by an expenditure of mental stimulus so small that we can scarcely recognise it. For the accomplishment of the act of writing a very large number of muscles is required, and when we consider the light yet firm grasp of the pen which is necessary, the poising of the hand in the semi-prone position, the stroke-making movements of the pen accomplished by the flexion and extension of the fingers, the travelling of the hand across the paper and back again, and the journey of the hand to the ink-pot, we see that nearly every muscle between the shoulder and the finger-tips is brought into play, and we cease to wonder that years are required for educating these muscles to work accurately and harmoniously together.

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[1] *Practitioner*, August 1872.

There may or may not be a ‘co-ordinating centre’ whose function it is to control the act of writing; this is a matter of speculation. It is, however, tolerably certain that, should one or more of the muscles which have been so laboriously educated exceed or fail in its work by an increased or diminished response to stimulation, the harmony of the complicated act of writing is interfered with, concord is converted into discord more or less marked, and that which had become a purely automatic act by dint of years of study, relapses again into an act which requires a greater or less amount of attention.

Now directly an act which should be automatic begins to demand our attention for its execution, the difficulties of executing such act are increased a hundredfold. Fear of failure, especially before others, is ever present to the mind, and it would seem as if a certain proportion of that mental stimulus which ought to animate the muscles suffered what we have called emotional diversion, and thereby caused increased muscular impotence. In every case of writer’s cramp that the author has seen there has been an emotional factor. Those who have had the most obvious physical cause for their troubles have complained that their troubles are worst in the presence of others, and especially when they have been called upon for official signatures before official witnesses. Emotional natures are those which are most prone to suffer from derangement of educated actions. We have seen one case, and only one, in which no cause, save an emotional one, could be discovered for the failure in writing, and it is right to state that there was nothing objectively wrong with the handwriting, the patient merely stating that 'he felt a difficulty.' In two or three others emotion, coupled with very trivial causes, such as alcoholism or slight neuralgia, had caused the difficulty, and in these patients again there was very little amiss with the writing. In two cases, rheumatic stiffening of one or other of the joints of the thumb had rendered certain combined movements impossible, and had thus destroyed the automatic character of writing. In two others, the troubles seem to have originated in stiffness of the shoulder and weakness of the deltoid (insidiously following rheumatism). In four cases a general strain of the arm had produced (through implication of the nerves) general weakness of many of the muscles. In one case paralysis of the ulnar nerve was the cause of the mischief; in another, weakness of the pronators from some cause occasioned the trouble, and in two others the failure of writing was the first indication of progressive muscular atrophy. In the remainder of the author's cases the difficulty in writing has been occasioned by excesssive use of the pen, and has arisen for the most part in persons of energetic temperament who have written against time to accomplish some task. In these the failure of writing was undoubtedly due to chronic fatigue of some of the writing muscles.

Now, immediately one small muscle—such as the first dorsal interosseous—fails, the act of writing ceases to be automatic. The attention of the scrivener is required, mental effort is necessary, and mental effort for the accomplishment of muscular acts means excessive stimulation of the muscles employed. When once the patient becomes conscious of his troubles, the disease is sure to spread rapidly; and, for the same reason, if he uses his left arm, it is sure to give out very quickly. In these extreme cases the patients invariably suffer from the acute pain of over-fatigue (sometimes accompanied by headache) whenever they attempt to write. The fatigued muscles will be found to respond less thoroughly to faradism than the healthy muscles of the opposite limb, and the patient either finds that voluntary action of these muscles is next to impossible or, if possible, is very quickly arrested by fatigue. In the author's experience it is not true, as is stated in most text-books, that all acts save that of writing can be perfectly accomplished. It must be borne in mind that for the accomplishment of most acts we have a great choice of muscles, and hence muscular failure may be difficult to detect; but it will be certainly observed that *all acts involving the affected muscles* are either impossible or performed in a clumsy manner. The phenomena of writer's cramp vary somewhat. They generally consist of mere impotence, without evident spasm or paralysis. Occasionally, however, there is cramp in the fatigued muscles, and sometimes spasm of the muscles which are antagonistic to them is observed. One definite cause of spasm is undoubtedly faulty antagonisation, and whenever we investigate local spasmodic action we must be careful to eliminate this cause.

A few words may be devoted with profit to the mode of examining patients suffering from loss of writing-power. The lesion causing such loss of power is often extremely obscure; and the greatest care and the most painstaking and prolonged examination are generally necessary for its detection. First, it is necessary to ascertain certain facts as to the family history of the patient and the history of his ailment, and for this end the following questions should be put. Is he a scrivener, and does he habitually, or has he at any period of his life, exercised the functions of writing to an excessive amount? How long has the disease existed, and did it come on gradually or suddenly? Does the patient attribute the onset of the disease to any definite cause, and did it clearly follow any extraordinary effort of writing or similar exercise, such as etching, drawing, or knitting? By the answers to these questions one is often able to get some insight into the case. If the patient be a scrivener, and if he attribute his loss of power to a definite cause, such as very excessive writing, one expects to find signs of chronic fatigue. If the loss of power came on absolutely suddenly, and after no extraordinary exertion, one would expect to find definite paralysis of one or more nerves or muscles. If the patient is not in the habit of writing excessively, and if the disease has crept upon him gradually and he cannot say definitely why or when, then one would expect to find the lesion to be in the nerves or nerve-centres rather than the muscles. A history of hereditary tendency towards writer's cramp or any other neurosis would of course materially influence both diagnosis and prognosis.

The next step is to strip the patient to the waist, and make a careful examination of the upper limbs, comparing one with the other. In this way any wasting of muscles will be detected, and the general state of muscular nutrition in both arms can be estimated. An examination of the nails, and the history which the patient gives as to the utility and quality of his nails, is of great importance as affording evidence of the state of nutrition. We have found thin, papery, brittle, pitted, or notched nails in very many instances. In the majority of cases the arms have been flabby and the reverse of muscular, and in two cases the right arm was in a trifling degree more flabby and less muscular than the left.

Ask the patient to write, giving him a large sheet of paper, a good quill pen, and something to copy, and notice very carefully how he sets about it. Look to the mode of pen-prehension, and observe whether or no the pen is readily arranged in the right hand, and whether the assistance of the left is required. Any difficulty in this points to weakness of the interossei or other intrinsic muscles of the hand, for the patient finds an awkwardness in producing those lateral movements of the fingers which are necessary for the comfortable settling of the pen in the writing position. It is of course absolutely necessary to ascertain exactly how the pen is held, and what muscles are employed for that purpose. Patients who have the disease in an advanced form can only hold their pens by some method more or less grotesque, such as grasping it with the entire hand, or interlacing it in the way one interlaces a penknife when using it for erasing. In others the pen-prehension is more natural, perhaps quite natural, or possibly the first finger is not used, or the thumb has its ungual phalanx bent at a right angle. Notice whether the pen is tightly or lightly grasped. Place the fingers on the wrist, and feel if the flexor tendons are tense or lax. Make him write with a soft cork penholder, and see if the force employed is sufficient to bend it. One patient snapped a cork penholder in two while trying to write with it. Is the pen too firmly pressed upon the paper? Are the lines too thick, and can one see daylight between the nibs of the pen? Observations on these little points may each give its quota of information. Next as to stroke-making. How is it accomplished? Whether by the flexion and extension of the fingers and thumb as it should be, or by movements of the wrist or shoulder? Does the patient keep his wrist upon the paper, or is the fore-arm raised by the elevation of the shoulder? What is the position of the hand and fore-arm? Is it poised as it should be, or is the position that of complete pronation, as may be the case where the weakness of the supinators is very marked? Always look for associated movements; for although we may be unable to explain them, they are nevertheless, we believe, a very certain sign of muscular weakness somewhere. The tricks to which a patient has recourse to overcome his difficulties are generally most instructive. As an example, we may mention the case of a gentleman who had a semi-paralytic condition of the musculo-spiral nerve, who was only able to write by pressing his fore-arm close to the trunk because (apparently) of the weak uncertain action of his supinators and triceps extensor.

Lastly, it is of importance to notice when and why the patient fails in his writing. Some cannot begin to write, and fail almost immediately; others begin very well, and only fail after a certain time. In the first instance the irritability of certain muscles will be found more evidently below par than in the second instance. Some are stopped by genuine spasm, some by tremor, some by an extreme and agonising sense of fatigue extending all up the arm, or felt only at certain points. And lastly, some are stopped by the evident 'giving out' of certain muscles. For example, in one of the author's patients with extreme weakness of the extensor primi internodii pollicis, the phalangeal angle of his thumb 'gives way;' in another the first finger refuses to remain on the pen; while in others the hand rolls over towards pronation or supination, or the pen slips from the fingers and evades the grasp from no very evident cause.

Next proceed to examine the irritability of individual muscles by means of faradism and galvanism, and their power of work by the performance of voluntary muscular acts involving, if possible, only one muscle or group of muscles at a time. Often a very decided lessening of faradic irritability is noticeable in certain of the normal or abnormal muscles of penprehension, but often the difference is not so much in the actual presence or absence of irritability as in the amount of contraction which follows the application of the faradic irritant. Occasionally it is found that some muscles not only respond too sluggishly to faradism, but that the same or others are too ready in their response to galvanism, which must be taken as evidence of nerve-change, and renders the prognosis bad. The power of voluntary movement possessed by individual muscles should be ascertained by making the patient perform not only the coarse movements, such as flexion, extension, pronation, and supination, but also a series of movements with each finger, so as to test the interossei; and by making him move the individual joints of his thumb, &c., always comparing the power of one side with that of the other. The question should always be put as to whether or no the patient experiences any difficulty in performing muscular acts other than that of writing. Thus a patient, in answering this question, told the author that he had considerable difficulty with certain acts, but not with others. 'For example,' he said, 'I can't draw a cork out of a bottle because of the screwing movement.' On questioning him still further, it was found that he was not able, without giving himself pain, to unfasten a carriage door, and that for this act he invariably used his left hand. On examining him, it was found that the act of supination was performed with difficulty, and occasioned great fatigue. In another case the exercising of the interossei muscles, by separating and approximating the fingers, was not only performed with difficulty, but its performance at once occasioned tremor. In performing these acts, it will be seen probably that some are far more readily performed than others, and that an intense feeling of fatigue is the immediate result of the attempt to perform some exercises.

It is obvious that for the satisfactory treatment of 'writer's cramp and similar professional ailments,' a correct diagnosis must be made ; for, after all, it is merely a symptom of disease which may arise from many different causes, of which 'chronic fatigue ' is one only.

There is hardly any disease for the relief of which so numerous and such various therapeutic agents have been employed as for the one we have been considering. The object of much of the treatment which has been employed has been to contrive by some means to avoid using those muscles which have become irritably weak. For this purpose Dieffenbach, Stromeyer, Aug. Tuppert, and others, have practised tenotomy with the effect of relieving the patent for a time, but with the almost invariable result of the return of the disease after a greater or less interval. By tenotomy the patient is simply compelled to employ other muscles for pen-prehension, and it might possibly have been expected that the complete holiday which the tenotomised muscle enjoys would have the effect of restoring its irritability by such time as, its tendon being re-united, it should again be called upon to exercise its functions. The results of tenotomy in this disease, however, go to prove that complete and forced inertness without any healthy exercise has not the power of restoring muscular tone.

Cazenave, and others who have imitated him, have thought to avoid the effects of the disease by providing the patient with some mechanical support for the pen, strapped to the hand or fore-arm. Means like this may enable a patient to continue to use his damaged limb, but it is evident that such arrangements are comparable merely to the starch bandage and the crutches which give to a man with a broken leg the means of progression. It is, however, impossible to write without a prolonged muscular strain somewhere; for even though the pen be strapped to the fore-arm, it is evident that the fore-arm has to be kept in a fixed and steady position for writing, and it generally happens that the muscles used in steadying the pen, however big and near to the shoulder they may be, sooner or later give out, as did their diminutive predecessors in the hand.

Amongst the so-called cures for writer's cramp are the methods of holding the pen coarsely, as by grasping it in the hand like a field-marshal's baton, or by using an enormous penholder, such as a walking-stick. Again, various forms of penholders have been devised, and we know of one case in which the patient manages to write by means of a penholder shaped like a peg-top, which he grasps tightly in his palm (by means of the flexors of the fingers); but it is evident that by shifts like these the disease is no more cured than an obstruction at the glottis is cured by means of tracheotomy.

Almost the only curative agent which has acquired any reputation is *rest*, and all writers on this disease are agreed that rest is always of the greatest importance. By rest we mean abstention merely from writing, not forced abstention from muscular acts of all kinds, for in this latter way there is a risk of causing atrophy of the weakened muscles, and but small chance of improving their tone. If the disease is treated early in its course, and the patient is able upon its first appearance to abandon writing for a time, the muscles recover their tone, and he is able to resume his occupation after an interval of a month or two. Patients in whom symptoms of writer's cramp have ever appeared should always be warned that they will never be able to perform an excessive amount of writing, and that any attempt to do so may be followed by disastrous consequences. If his occupation be that of a writing clerk, it is, we think, absolutely necessary for his future happiness that his employment should be changed, perhaps not entirely, but lightened at least, by finding some employment which may alternate with the periods of writing. To allow a patient with writer's cramp to continue his excessive writing is like allowing a dyspeptic to continue with the diet which we know is the cause of his dyspepsia. We may here perhaps remark that we believe there are very many cases of incipient writer's cramp to be found in public and private offices, and it is very common to find that a clerk begins to hold his pen in some queer way merely because he gets on better with the new method than by the old. If such cases were carefully examined, we should often possibly detect a weakened muscle. It is a matter of fact that writer's cramp rarely comes under the eye of a physician till it has existed months or years, and has made considerable advances. The patients go on for indefinite periods of time, merely thinking that their hindrance arises from their own stupidity; and it is only when the various shifts for relieving one muscle after another have been unconsciously employed and exhausted, that the patient seeks advice.

Liniments and douches have been often prescribed, and in so far as they may quicken nutritive processes, we believe them to be useful. One patient with a neuralgic condition of the musculo-spiral nerve experienced some relief from using an aconite liniment.

Gymnastic exercises have been used and have enjoyed a certain reputation, and if such gymnastics be directed towards the rhythmical exercise of the affected muscles, much good may be done. The muscles become weakened and irritable because, in the words of Sir James Paget, 'the rhythm of nutrition is perverted;' and by the employment of rhythmical exercises very much benefit may result.

With regard to drugs and constitutional treatment, we may say that everything which improves the patient's general health is capable to some extent of improving his local ailment; and while his local ailment is under treatment, it is absolutely necessary to regulate with great care the functions of the body. The nervine tonics are all useful, but must not be used indiscriminately. We have found strychnine of great service in one or two cases where the patient's general health was much below par, and was accompanied by a state of mental depression. In highly nervous excitable people, and especially in one case where there was distinct muscular spasm, it was found that strychnine served merely to increase the patient's condition. In such cases, and especially when the patient is excitable and anxious, nervous in the presence of others, and a bad sleeper, the greatest possible service has resulted from the administration of bromide of potassium.

With regard to local treatment, the same principles should guide us as in the treatment of all other diseases, viz. remove the cause, and heal the damaged parts. The patient with advanced writer's cramp should be forbidden to write at all for a time. The mechanism of writing and the cause of failure should be fully explained to the patient, a proper and normal prehension of the pen should be insisted upon, and he should be prevented from grasping the pen too tightly and from using for this purpose any but the proper muscles. This may be done partly by precept and partly by making the patient write with a soft-pointed instrument. The use of quill pens should be insisted upon, or a soft pencil or fine-pointed paint-brush may be used for practising writing. The patient is generally in the condition of a child as regards the act of writing. Not only has he to learn afresh how to hold and move his pen, but he has also to unlearn the vicious modes of writing into which he has been forced by circumstances.

We have two means of materially improving the condition of the affected muscles. One is the application of electricity, and the other is rhythmical exercise. With regard to electricity, it is probable that galvanism continually applied is preferable to faradism. We are well award that faradism has been used with advantage by Zuradelli, Meyer, Haupt, and Dr. Buzzard; but one cannot but feel that faradism must be rather a dangerous application, and that by using so powerful a stimulant we run no small risk of exhausting what little irritability remains in the muscles. In the hands of most physicians faradism has done no good, and Duchenne says very definitely that its employment, even by himself, has not been followed by success. It will be remembered, too, that of Dr. Buzzard's two cases reported in the 'Practitioner' for August, 1872, one appeared to be a case of definite local paralysis rather than true writer's cramp. The great use of faradism is undoubted in cases where voluntary movement is no longer possible, but where voluntary power remains we are by no means sure that artificial stimulation of the muscles is to be recommended. Our mode of using the current is as follows:—One pole (the positive) is placed, let us say, in the axilla, and the other over the ulnar nerve just where it leaves the edge of the biceps muscle *en route* for the olecranon. The strength of current is short of that which causes muscular contraction, but is just sufficient to make the patient conscious of a tingle in the end of the little finger when the circuit is made or broken. The patient is then made to exercise the interossei by separating and approximating the fingers rhythmically. Take another example:—The positive pole may be placed over the median nerve at the inner border of the biceps, and the negative over the body of the flexor longus pollicis, while the patient is made to flex rhythmically the distal phalanx of his thumb: or again the positive pole may be placed high in the axilla, and the negative over the musculo-spiral nerve as it turns forward alongside the supinator longus just above the bend of the elbow; and the patient is then made to supinate the hand or extend the fingers rhythmically.

The anodyne effects of the galvanic current are well known, but there is probably no form of pain over which it has such complete control as the pain of muscular fatigue, the form of pain, be it observed, with which we have to deal in writer's cramp. Its power over some forms of spasm, one of the occasional complications of writer's cramp, is also well known.

The effect of this mode of treatment in five cases which the author has treated himself has been most marked, alleviation of the patient's distress following immediately on the first application. With regard to treatment, one must remember Trousseau's dogma, *Longue maladie, longue traitement;* and it is not rational to suppose that a condition which has often existed for years before it comes under the eye of the physician can be cured without many months of patient and systematic attention. The worst two cases we have seen, the only two, in fact, in which the loss of writing-power was total, have been treated in the manner indicated, and with marked success.

Case XXI.

Writer's Cramp. Reported by the Author in the Practitioner, Vol. 2, 1873.—Henry Millerd, æt. 40, in the employ of the General Post Office, came to consult me at the Charing Cross Hospital on October 5, 1872. He is a 'nervous' man, has suffered from neuralgia, and has one sister who suffers from paraplegia. Has done an immense amount of writing during the last thirteen years, often writing 'against time.' States that in the summer of 1868 he felt that he had lost control over his pen, and was obliged to grasp it tighter. He managed, however, to continue writing tolerably well till April 1872, when 'he lost control over the fore-finger,' and was obliged to begin holding his pen by interlacing it among the fingers. He cannot rest his wrist upon the desk when writing: if he does so, the fingers and thumb 'start away from the pen.' He complains of deep-seated pain in the wrist-joint, and in the carpo-metacarpal joint of the thumb. He has now completely lost the power of writing with his right hand, and has learnt to use the left; but, strange to say, he is quite unable to write with the left hand without making spider-like movements with the fingers of the right.

Any attempt to use the right hand causes agonising pain from the shoulder downwards. The pain is the pain of intense over-fatigue, and does not follow the line of the nerves. On stripping him it was found that there was nowhere any detectable wasting of any muscle, but that both arms were soft and flabby, and the right rather smaller than the left. On being asked to write, the whole body seemed to take part in the exertion; the pen was grasped as tightly as possible, the fore-arm raised off the table, the shoulder elevated. An incomplete signature was all that could be effected, and the attempt caused great pain in the limb. On testing with faradism, it was found that the interossei, the abductor pollicis, the flexor longus pollicis, and the extensor primi internodii on the right side, contracted far less readily and less forcibly than their fellows of the opposite limb. Voluntary movements of these muscles were performed with the greatest difficulty, as was also the movement of supination, which could only be effected four or five times in succession, notwithstanding the strongest efforts to do so. The phalangeal joint of the right thumb has a curious habit of 'snapping' audibly at intervals, which is due, apparently, to the spasmodic and unequal action of the muscles moving it. The nails of both hands are very bad, being 'pitted' in an extraordinary manner.

His condition is ever present to his mind, and his mental state is one of great depression, his writing-power being his source of income. Lithographed fac-similes of this patient's handwriting are given, which show how rapid was his improvement under treatment. On the first application of the current the pain in his arm disappeared, and within a week of its first application he could manage to sign his name with tolerable ease. His writing from this time rapidly improved, and at present his handwriting, when he is allowed to use his right hand (which is very seldom), is, as far as appearances go, as good as it ever was. Samples of his handwriting are given in the accompanying lithograph. The first three samples were written respectively on October 5, 12, and 21, and the fourth on November 1. The other two samples are dated. Although the handwriting is now very good, the pen-prehension is still faulty, and I have forbidden him to write until he can do so with the pen held properly and lightly between the thumb and first two fingers. Pen-prehension has gradually very much improved, and it was soon noticeable that the effort of writing had much decreased, and such efforts soon ceased to cause fatigue. First, the elevation of the shoulder disappeared; then the fore-arm could be rested on the table during writing. Next, the phalangeal angle of the thumb no longer gave way, and now he can write very comfortably if he holds the pen only between the thumb and first finger (at one time the first finger could not be placed on the penholder), but any attempt to use the middle finger bothers him very much. On testing the muscles with faradism, it is now found that the dorsal interossei on either side of the middle finger respond *far less* readily than their fellows of the left hand, but that the other interossei, which were weak in the first instance, have recovered their normal irritability. Earlier in the case it was evident that the dorsal interosseous muscle on the radial side of the middle metacarpal bone was less irritable and more weak than the one on the ulnar side; and by placing a rheophore on the metacarpal bone so as to influence equally the muscles on either side, the first phalanx was flexed, but dragged by the stronger muscle towards the ulnar side.

The galvanism has been used in the manner stated above, and the variety of exercises which he has been made to practise is very great. Especially he has been made to hold a pen or pencil, or my finger, and to perform with it the movements of writing a hundred times in succession, while the current has been applied alternately to the nerves supplying the muscles implicated. At first the difficulty of this exercise was extreme, the pen frequently slipping from the grasp of the fingers. At present it can be performed without any difficulty whatever. The only movement at present in performing which there is the slightest difficulty is the waggling of the middle finger from side to side by means of the interossei. It was noticeable very early in the case that the fore-arm had got firm and muscular, and that the pitting had disappeared almost entirely from the finger-nails. The patient's enjoyment of the current is quite remarkable, and during its application he frequently uses such expressions as 'That's comforting,' 'That seems to give me strength,' &c. The general health has much improved, a fact which is attributable in great measure to the removal of the cause of his mental depression, as well as to the mixture of strychnine, perchloride of iron and nitro-muriatic acid which he has been constantly taking. The snapping of the thumb has almost disappeared, and is now far less frequent and less loud.

He has continued to use the left hand for writing while he has been under treatment. The movements of the right fingers while writing with the left hand have quite disappeared. Once or twice he has complained of a feeling of awkwardness with the left hand, but this has always been immediately removed by the current. The amount of writing which he has done during the treatment has been about two hours a day, but this amount had to be performed often rapidly and *against time.*

In cases of failure of writing power the author does not recommend an electrical treatment, unless the case is attributable to chronic fatigue or some paralytic condition, for the treatment of which it has an acknowledged reputation.

The following case which presents features almost unique

1. Henry M

2. Henry Miller

3. Henry Millerd

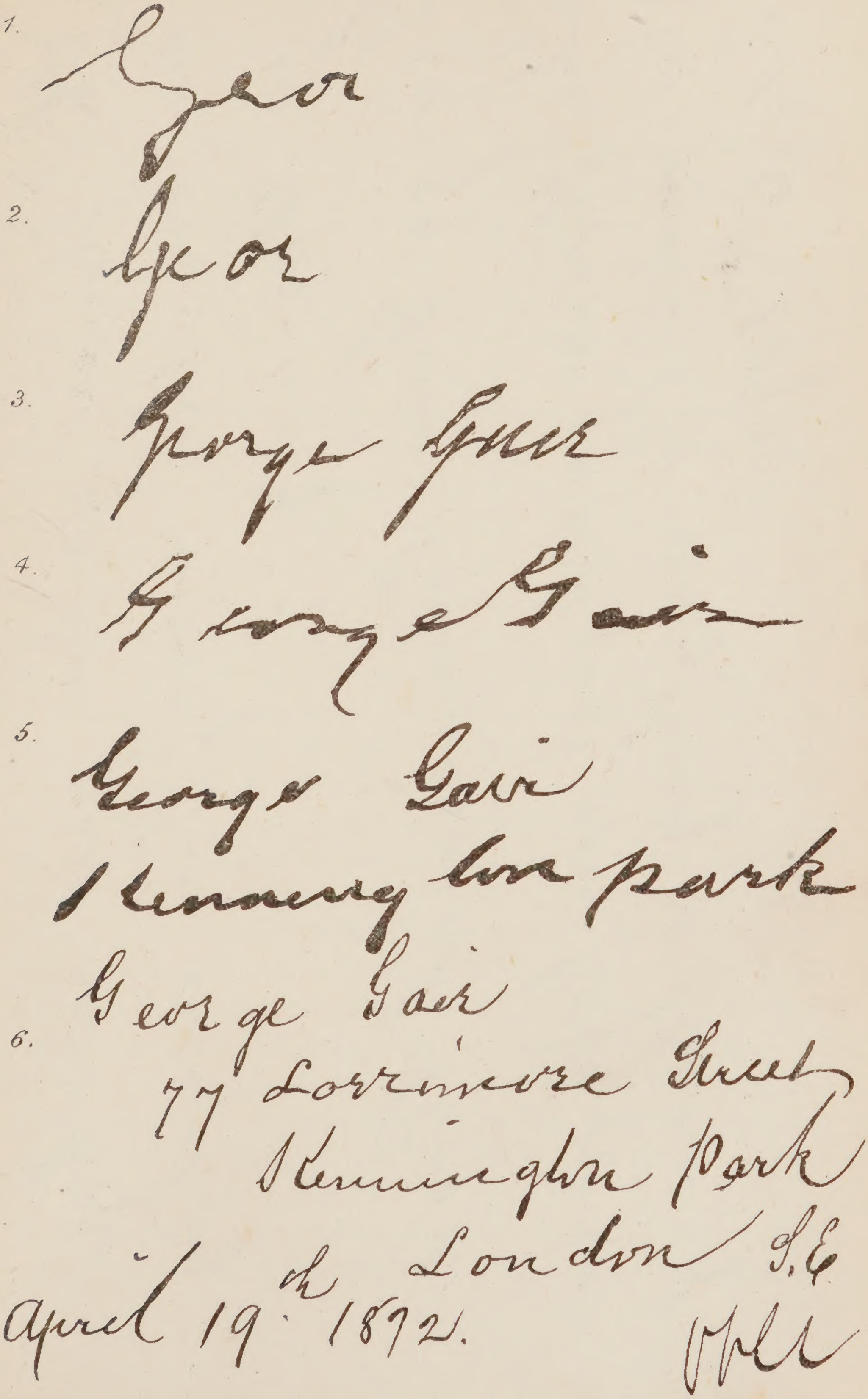
2 Oct 1872.

4. Henry Millard

Henry Millerd
14/12/72
5: 173 Manor St Clapham

The weather is fine but cold
6 Henry Millerd
24 March 72

Written while resting my wrist on the desk



1. Geor

2. Geor

3. George Gair

4. George Gair

5. George Gair
Kennington park

George Gair
6. 77 Lorrimore Street
Kennington Park
London S.E
April 19th 1872.

7. The flower garden just now keeps
us on the move, for everything
is blooming

8. George Gair Commercial Road

9. The flower garden just now keeps us on
the move for everything is blooming
July 31st 1872

was communicated by the author to the 'Practitioner' in September 1872.

Case XXII.

'*Writer's cramp,' and subsequent general spasm of the right arm, treated by the joint use of the continuous galvanic current and the rhythmical exercise of the affected muscles.*

George Gair, aged 32, single. A small man, well made, rather muscular, and of very healthy appearance. No history whatever of any hereditary neurotic tendencies. Has always enjoyed most excellent health. He has always been steady, and, while able, was hard-working and industrious; has never had syphilis. He is a well-educated and very intelligent man. He left school when fourteen years old and became a writing clerk in a commercial house in the city. He wrote an excellent hand, and gained rapid promotion in his office. In the year 1859 he left his situation and entered an accountant's office, where he did, on an average, nine hours' writing a day. By reason of his neat style of writing he was constantly employed in copying balance-sheets. In this situation, in which he remained for fifteen months, he earned five pounds a week, and there can be no doubt that the amount of writing which he was called upon to do was something prodigious. He left his situation because of his present illness, which came on almost without warning of any kind. He had been working as well as ever, when one day, towards the close of his day's work, he says, 'he had a difficulty in bringing his right hand down upon the paper.' He managed, however, for that day and for the three following days to continue his writing by holding his right wrist firmly on the desk with his left hand. At the expiration of three days he found himself wholly incapable of accomplishing the neat work required of him, and he had to leave his employment.

For about a month subsequently he managed to write a few letters by steadying the palm of his hand against the edge of the desk and only using his fingers. Between that date (October 1862) and January 1872, he has been totally unable to accomplish any writing at all with his right hand. He gradually acquired the art of writing with his left hand, and what writing he has absolutely been required to do has been accomplished in this way. During last year, however, the left hand began to suffer from cramps and ultimately became as stubborn as the right. His means of subsistence being taken from him, he was obliged to live upon his savings, which were considerable; but his store of money gradually diminished; and about the middle of last year he began to experience real want and to be filled with apprehension for the future.

About this time, and probably as an effect of his straitened circumstances and anxiety of mind, his right hand, which hitherto had refused to write only, began to be affected with spasms at other times. He gradually had lost the power of using his knife at dinner, and occasionally he found himself unable to accomplish the most ordinary acts by reason of sudden spasms of the muscles of his right arm. Shortly before I saw him he had broken the jug belonging to his wash-hand basin, in consequence of a sudden spasm just as he was about to pour out some water.

During the six weeks previous to his coming under my observation there had been a further exacerbation of his condition, and the right arm had become liable to sudden spasms even when not called upon to perform any act. It was the seat of an exaggerated local chorea; it was always jerking about, and at times would bounce out of the side pocket of his coat as he was walking in the streets. These strange antics naturally attracted attention, and immediately the patient saw that he was observed the spasms became doubly severe. In January of this year he came under my notice at the out-patient department of the Charing Cross Hospital, and the following account of his then condition is taken verbatim from my note-book :—‘ On asking him to strip himself to the waist, he does so without difficulty. There is no evident impairment of the nutrition of the muscles of his right arm. The right arm hangs by his side and is subject to constant twitchings. The deltoid, the pectoralis major, the scapular muscles, as well as the biceps and triceps, are all affected; but the last-named muscle is the worst offender, and in it the cramps are more constant and more severe than elsewhere. While I am talking to him the arm is forcibly extended, and the triceps is as tense and hard as a board. The fingers and wrist are often flexed, but never extended. The thumb and fingers do not seem liable to spasms individually. At times the spasms subside for a few moments, but any allusion to them seems to bring them back.' [This apparently was due to nervousness, and was exactly analogous to the extra difficulties experienced by a stammerer when attention is called to his defective speech.] 'On being requested to perform any act, the right arm "jibs," as it were, like a stubborn mule, and it is only by main force and by the greatest concentration of thought and determination that the most simple things can be accomplished. Everything is done with the arm extended. On being asked to unlock a box which lay on a table, the arm was stiffly extended, and the patient, standing of course at arm's length from the box, managed with great difficulty to unlock it.

'Of all acts, writing occasions the greatest amount of spasm. On asking him to write his name, he takes the pen in hand, and immediately he does so there is a violent cramp of the triceps; the arm is forcibly extended, and with great difficulty he manages to write "Geor" in a manner scarcely legible, when the hand is twisted off the paper by a violent rotation of the wrist, and his fingers lose the grasp of the pen. On asking him to continue writing, he is perfectly unable to do so, and every effort even to place his hand on the paper seems to be violently resisted by every muscle from the deltoid downwards.

'The spasms of the arm never come on during sleep. He states, however, that latterly, owing to mental worry, he has slept very badly.'

So much for the history of the case and the condition of the patient when he first came under observation. At the beginning of July last he furnished me with an account, *written by himself*, of the various treatments to which he has been subjected between 1862 and the present time. I give it in his own words.

'1. Galvanism three times a week and manual labour, such as digging, &c. Was under this treatment for about six months, and derived no benefit.

'2. Sea-bathing, cold water pumped or poured on the arm about every two hours, exercise with the dumb-bells, rowing, gymnastics, &c. Was under this treatment for about three months. No benefit.

'3. I was now advised a sea-voyage, but instead of taking one I obtained a situation as steward on one of the boats running between Bristol and Cardiff. I tried this about three months, but no improvement.

'4. Galvanism twice a week, and one of Pulvermacher's chain bands worn round the arm. I was also to use the arm as much as possible. I was under this treatment twelve months, but got gradually worse.' [He has a couple of scars on his right arm, the result of a burn by Pulvermacher's chain band.]

'5. Cold shower-baths and friction with horse-hair gloves every morning, and the spine rubbed with croton oil three or four times a week. I was considerably worse after twelve months of this kind of treatment. I have also had Measam's cream and various oils rubbed into the arm at different times.'

This account is accompanied by fac-similes of his handwriting at various times between January 20 and the present date, so that by a reference to it the reader may see how gradual, but at the same time how continuous and satisfactorily, the improvement has been. The man himself is an excellent patient, and has followed out with the most scrupulous care and dogged perseverance every suggestion which has been made to him.

The published cases of 'writer's cramp' and the articles upon the subject in our text-books gave one very little hope of bringing about any improvement; but as such cases are of a peculiarly interesting nature, I resolved to try every therapeutic agent which seemed in any way applicable. First small doses of strychnine were given, but as the patient said very decidedly that the medicine made him worse, they were soon discontinued.

Mental irritation and distress and sleeplessness being marked features, bromide of potassium was given and with excellent results, for it procured good night's rest, and seemed to diminish a little the spontaneous spasm of the arm. This seemed to be due to his paying less attention to his condition. His power of writing showed no improvement after the bromide alone; but in consequence of the sleep and mental ease which it seems to give, it has been continued in doses of fifteen grains three times a day throughout his whole case of treatment.

From the very first *rest* was enjoined. In order to make quite certain that the arm could be used for nothing at all, I first attempted to put the whole of the arm in an immovable apparatus of plaster of Paris, but this did not succeed, for the spasms were so violent and constant that it was impossible to get the plaster to 'set' properly, and very soon the rough ridges which formed in the bandage began to bruise the arm. The plaster of Paris was therefore removed within forty-eight hours of its application, and the patient was merely ordered to keep his arm in a sling. To this he adhered rigidly for two months or so, and then, the general spasm having much diminished, he was allowed gradually to use his arm more and more, and at the present time he is allowed to use it as much as he likes for every purpose except that of writing.

I first saw the patient on January 20, and for the first three weeks the above methods of treatment were alone employed.

On February 8, in addition to the bromide of potassium and rest in a sling, I commenced the use of the continuous galvanic current. At this date he had improved somewhat in so far as his condition bothered him less, and he always slept soundly at nights. The general spasms of his arm were still as bad as ever, and his inability to write had not in the least abated. The improvement in his mental condition, which served as it were as a solid foundation for his further treatment, was due, in my opinion, entirely to the bromide of potassium, which he still continues to take.

The galvanic current was used in a peculiar way, and, as a reference to the accompanying fac-similes of the patient's handwriting will show, with the best results.

A slight explanatory digression here becomes necessary. In searching for a cause for this man's condition I was completely baffled, so that it seemed useless to proceed as in other diseases and attempt to remove it. There was no indication of any disease of the spinal cord, such as Mr. Solly, in his paper on this subject, hinted at as the probable cause of the cramps. The man, with the exception of his right arm, was perfectly well. I could find nothing wrong with him. His digestion was excellent, and he was capable of any amount of physical exertion. With the exception of the spasm, I could find nothing wrong with his right arm. There was neither hyperæsthesia, paræsthesia, nor anæsthesia of any part, and no paralysis of any of the muscles. The spasms themselves did not point to any particular nerve at fault. All the muscles of his right arm and shoulder were in a state of revolt, refusing to obey orders, and the worst offender and ringleader appeared to be the triceps extensor.

The case seemed to me to be analogous to stammering. This man stammered with his right arm; and just as ordinary stammerers while they haggle over everything find special difficulty with certain words, so this man's arm, while it jibbed as it were at every orderly action, was especially stubborn when called upon to write.

Now, every stammerer that I have ever met can sing.

They are all capable of a rhythmical use of the voice, and every stammerer has, I believe, his cure within his own grasp if he persevere in the orderly and rhythmical exercise of his vocal powers. Regular, orderly, continuous and rhythmical *drilling* converts as it were his 'awkward squad' of muscles into obedient and well-disciplined servants of his brain. I determined to apply the above principles to the treatment of a stammering right arm.

It was necessary, however, to get rid of the spasms by artificial means before the rhythmical exercise could be commenced. For this purpose one of Weiss's continuous current batteries was employed, and twenty-three cells were used to begin with. The sponges, being well wetted with salt and water, were first placed on either side of the belly of the deltoid muscle (which at the time was the seat of almost continuous spasm). The spasm immediately subsided, and then the man was made to exercise his deltoid while I counted 'one, two,' 'one, two,' like a drill sergeant, every time he elevated or depressed his arm, the patient keeping time to the counting.

Other muscles were then exercised in the same way—the pectoralis major, biceps, triceps, pronators, supinators, and the flexors and extensors of the wrist and fingers, care being taken not to overtire the muscles. Every possible kind of rhythmical exercise has been gone through. The pectorals have been exercised by practising 'extension movements' and drawing back the shoulders, and the fingers and thumb have been also drilled by opposing the thumb to every finger in turn, and by making him run along the mantel-piece or the table with his fingers as if playing the piano. It is unnecessary to detail the way in which the galvanic current was employed for every muscle or group of muscles, but the samples quoted will serve to show the principle. The good effects of this plan of treatment were soon manifested. It was commenced on February 8. On the 9th, the patient stated that 'his arm had been remarkably quiet since the electricity yesterday;' and on the 11th, he said that he had already derived so much benefit that his arm was no longer a nuisance to him, but, on the contrary, he was able to use it for dressing himself; and on the 12th, he buttoned his collar, which he had not done for months before. A reference to the lithographed fac-similes of his handwriting will show that this too began to improve in a most remarkable way. The galvanism and rhythmical exercise has been continued every day without intermission from February to the present time, and the patient still continues to make gradual and marked improvement. He can now accomplish everything, except writing, with perfect ease, and even the power of writing has improved in a very great degree. He has written me two or three letters, and has been able to embark in a small business. When he writes, he says, he feels like a schoolboy beginning to learn, and the act of writing is gradually becoming more easy to him. The great bar to his writing hitherto has been the triceps muscle, which, till recently, has taken on a spasmodic action whenever he has taken a pen in his hand ; and all his writing has been hitherto accomplished with the arm forcibly extended. This condition of the triceps is being gradually overcome, and the eighth sample of handwriting was written 'with the greatest ease, and with the arm bent.'

In addition to the galvanism he has had a daily hypodermic injection of morphia (gr. $\frac{1}{6}$). I do not think that this was of any decided benefit to him. It has been discontinued now for the past six weeks, and his improvement has been, I think, more rapid since. At the beginning of June the galvanism was discontinued for a fortnight while the battery was under repair, and it was gratifying to find that during this time he suffered no retrogression.

I append the dates and a few remarks concerning some of the specimens of handwriting.

1. Written on January 20, 1872, before the adoption of any treatment.

2. Written on February 8, after first use of the galvanic current.

3. Written on February 9. The word 'Gair' was written while the sponges were held on the front and back of his forearm.

4. February 14.

5. Middle of March.

6. April 19.

7. July 6.

8. July 25. Written with the arm bent and 'with the greatest ease.'

9. July 31.

I have to express my thanks to my friend Mr. Horatio Symonds for kindly undertaking the care of this patient during my absence from home, in March, April, and May.

Case XXIII.

'Artisan's cramp,' treated by the joint use of the galvanic current and rhythmical exercise, under the care of Dr. Hilton Fagge (from notes kindly furnished to the author by Dr. Fagge) :—

T. W., æt. 58, a whitesmith. Has always had good health. No history of syphilis, rheumatism, or intemperance. Had a blow on the head with a hammer when twenty-two years old, but was well in three weeks. Had a 'family trouble' when fifty years old.

Four months ago noticed a tingling at the tips of his left thumb and index finger after using his hammer. (His work was of such a character that while his left arm had the heavier work his right was used in striking rapid blows with a light hammer.) These became painful and gradually increased in extent, until at the fourth week it had extended to the back of the right axilla. Says that the pain was so unbearable that when the pain came on suddenly in the street he was compelled to cry out by the agony it caused. About this time he noticed that he was unable to use his hammer for a long time together on account of a crampy feeling and inability to grasp it firmly, the hammer falling from his hand. This condition continuing, and finding he only got worse after a week's rest, he came here (Guy's Hospital) as an out-patient to Dr. Fagge.

The right arm is not so muscular as the left, but this he says has always been the case from the difference in their work. He is muscular and healthy-looking.

January 20.—Held out right arm at a right angle for two minutes, when it got very tired. Continuous current then applied first from over brachial plexus (+) to deltoid (–), and then as there was quivering in biceps and forearm, the negative pole was removed to inner side of the bend of the elbow, but without diminishing the sense of weariness, though contractions were caused and the quivering ceased. After a rest galvanism was applied to the following parts, slow rhythmical voluntary contractions of the muscles concerned being made at the same time (about thirty-six in the minute).

15 cells for 2 minutes from Brachial Plexus (+) to back of Deltoid.
" " " " Biceps.
" " " " Muscles of forearm.

Patient said he felt stronger in the affected arm than he had been.

Jan. 21.
15 cells for 3 minutes from Plexus (+) to Biceps (–).
{15 cells, then 10, then 5, on account of pain} " " " Inner side of Biceps (–).
15 cells for 2 " " " Back of Deltoid.

Note.—When the negative pole was at inner side of biceps, voluntary grasping movements were used. Patient said he could grasp much tighter than before.

Jan. 23.

15 cells for 3 minutes from Plexus to forearm (anterior surface near elbow).
,, 2 ,, ,, outer edge of lower end of biceps.
,, ,, ,, ,, back of Deltoid.

Week ending January 31.—Galvanism applied in the ordinary way (not Dr. Poore's) on three occasions.

February 5.—Galvanism applied as on January 23. Can now move his arm as well as ever. Complains, however, of great pain in his hand which comes on at times.

February 11.—Galvanism has been applied, as on February 5, up to this time. The pain gradually left him, being last felt down the arm to the index finger; but this has now disappeared entirely. Discontinued treatment.

February 21.—Has now worked for a week as well as he ever did. His only trouble now is a little darting pain in the arm at night after work. None whatever while at work.

Cases XXIV.

Writer's cramp (*Dr. Buzzard*, '*Practitioner*,' *August* 1872) :—

A gentleman, aged twenty-seven, whose occupation had entailed a good deal of writing, consulted Dr. Buzzard in February 1869. For two or three years he had noticed that his right arm was liable to get stiff and numbed after writing, and during the last year there had been a constant tendency for his arm to roll outwards directly he began to write. He could now scarcely write a word. There was also a difficulty in other acts, such as driving, lifting objects, shaving and dealing cards.

Family and personal history was slightly 'neurotic.' Five or six years ago he had suffered inconvenience for a day or two by falling from his horse and striking the back of his neck. As a schoolboy he had been cautioned by his schoolmaster because he was accustomed to hold his pen with undue tightness. Rest, keeping the arm in a splint, and liquor arsenicalis, did him no good, and on April 13 he was as bad as ever. In view of the spasmodic action of the supinators, the antagonistic muscles, the pronator radii teres and the flexors were ordered to be faradised three times a week, a dumb-bell to be employed in movements of pronation only, and rest in a splint to be continued for six hours daily. This treatment was continued till June 19, when it was found that the girth of his arm had increased three-eighths of an inch. From this date faradism was omitted, and in a fortnight the increased girth was lost again. Treatment was sedulously continued (by Mr. Bond Moore, of Wolverhampton), and by January 30, 1870, the girth of the arm had increased three-quarters of an inch. Treatment (faradism and arsenic) was continued, and 'there was gradual improvement in the co-ordinating power.' On November 5, 1870, the following note was made :—'He can write now without inconvenience. The hand will sometimes incline to roll over, but never entirely does so. He can shave himself now, and carve at table perfectly well, which he could not do formerly. He can deal cards now with ease.'

Dr. Buzzard remarks : 'It is interesting to note that the development of the size of the fore-arm in response to the faradism was accompanied by diminution of cramp, whereas when the electrical treatment was suspended from any cause the arm grew smaller and the cramp returned. The patient himself thought that he derived great benefit from the arsenic, which he took for fifteen months. He found that under its use the bilious attacks and indigestion from which he had been apt to suffer almost entirely disappeared. No doubt these attacks were of nervous origin ; both in his family and personally there is a neurotic history. Obscure as is the pathology of such cases, one would be disposed to consider his local ailment as being due primarily to a central cause—a peculiar condition of nerve cells constituting a centre of co-ordination.'

The following case occurred amongst the out-patients of Charing Cross Hospital, and is, for pathological as well as therapeutical reasons, well worth attention :—

CASE XXV.

Clonic torticollis, treated by galvanism and rhythmical exercise.

Catherine K., a needlewoman, aged thirty-four, was admitted as an out-patient on February 27, 1873. The neck was the seat of an almost incessant violent clonic spasm. During the spasm the following phenomena were observed: the chin was twisted towards the point of the left shoulder, and at the same time the neck was bent towards the left side. The left shoulder was elevated, and almost every movement of the neck was accompanied by a flexion of the left arm which brought the hand close to or in contact with the chin. The spasm was so frequent and so severe that a raw place about the size of a sixpence had been produced on the skin covering the left ramus of the lower jaw midway between the angle and the symphysis, by the constant impinging of this point on the left shoulder. The patient also complained of pain—a sore pain—'like a broken bone,' as she said, over the region of the left trapezius muscle, but chiefly at a point midway between the acromion and the occiput, and about an inch and a half posterior to the free edge of the muscle. There was also pain, a feeling of weakness, over the nape of the neck. This pain was always present to a certain extent, but was much aggravated by movement. The muscles which seemed mainly at fault were the right sterno-mastoid and the left trapezius. The patient states that her needlework is done with the hand, not the machine; that at times she has had to work very hard at it; and further, she distinctly says that all the distress in doing her work (which consists mainly in the sewing of heavy materials, such as bed-ticking) is felt in the left hand and arm, which supports the material, and not in the right which plies the needle. In this assertion she is borne out by other needlewomen who have been consulted on the point.

In July 1872, she was working very hard, and had the misfortune also to lose her little boy by drowning, which caused her much grief and anxiety. It was at this time that she first felt a slight unsteadiness and tremor of the head.

In September 1872, she first felt the head twisted to the left shoulder, and this slight twisting continued till Christmas, when, during a slight respite from needlework, it left her entirely for a couple of days. On the morning of December 26, she says, 'as she was preparing breakfast her head was suddenly twisted so violently to the left that her whole body was compelled to follow it, and she was rotated forcibly on her feet.' From that time the spasm continued, and about the middle of January 1873, her left arm began to be flexed at each turning of the neck. From that time her condition got gradually worse.

On February 28 she was admitted into the hospital, and her treatment was commenced. A galvanic current generated by from six to twelve cells of a zinc-carbon battery, constructed by Messrs. Meyer and Meltzer, was applied as follows to the regions supplied by both spinal accessory nerves :—The positive pole was placed at the highest accessible point of the nerve behind the ear, between the ramus of the jaw and the mastoid process. The negative pole was moved over the whole region of the terminations of the nerve, from the sterno-mastoid muscle in front to the lower angle of the trapezius muscle behind. At the same time the muscles were exercised rhythmically, and the patient was made to shrug the shoulders, nod, and rotate the head, keeping time as she did so to the counting of the physician. During the passage of the current the spasms almost entirely ceased, and the movements were performed with scarcely any interruptions. The left arm also was exercised rhythmically during the passage of a current, one pole being held in the hand and the other being placed over the upper part of the cervical spine. The entire sitting occupied about twenty minutes.

Her improvement was marked and rapid. On March 1 she stated that 'her head had hardly twisted at all since the electricity yesterday.'

The treatment was repeated daily, and the pains soon completely disappeared, and the spasms became gradually lessened. After a very few days the spasm became amenable to the voluntary control of the patient—that is, that as long as the head was kept turned *to the right* no spasm occurred, but if the chin approached the line of the sternal notch the head was suddenly twisted over to the left shoulder in the old style. At first the head was always kept *very much* over to the right side, and, to use the patient's expression, it was 'only when she forgot herself,' and allowed the head to assume a normal position, that the spasms occurred. The case, which originally was one of left clonic spasm, would have appeared about the middle of March to have merited the name of a right tonic spasm.

At present the spasms are only of very rare occurrence, and the head is carried so slightly turned to the right as to be hardly noticeable.

At first the patient could not sleep on her right side because that position brought the chin to the middle line, and spasm followed, and it was not till the middle of May that she slept on the right side, 'the first time she had done so for many months.'

The patient left the hospital on April 10, being quite well enough to resume her ordinary household duties. She was warned, however, that any attempt to continue her old occupation of needlework would almost undoubtedly result in the return of her old symptoms. Since leaving the hospital she has attended as an out-patient. Cases like this are often thought to be malingerers. It is right, therefore, to state that this patient was carefully watched, and that she was seen by many of the medical staff of the hospital, all of whom agreed that the question of malingering was not tenable.

The author regards the case as a sample of a fatigue disease, and as analogous in some respects to writer's cramp, the proximate cause of the symptoms being the tiring out of the muscles which support the left clavicular arch. The patient was a needlewoman, and accustomed to support heavy materials, often for hours together, on the left arm. The constant weight on the left arm is necessarily felt at the left clavicular arch, and the muscles supporting that arch are compelled to exercise their physiological functions for inordinately long periods at a time. The muscles implicated were the left sterno-mastoid and the left trapezius, and, as a consequence, they became irritably weak, and drifted into that condition which may be called a state of chronic fatigue. This condition of the muscles seems to have produced an irritable and painful condition of the spinal accessory nerve, for although this nerve is spoken of as being entirely motor in its function, it is nevertheless sensitive when irritated. There is no more painful process than the faradisation of the branch of this nerve which supplies the trapezius. With regard to the painful spot observable in this patient just beyond the border of the trapezius, it may be remarked that the pain was not aggravated by pressure, but very much so by contractions of the muscle. The irritation of the terminal branches of the left spinal accessory seems ultimately to have been reflected to the terminations of the nerve on the opposite side—its antagonist—and to have produced spasmodic contractions of one of the muscles supplied by it—viz., the right sterno-mastoid. When the patient was at her worst, the right sterno-mastoid was constantly overcoming the antagonising action of the left sterno-mastoid, irrespective of the position of the head ; but as the patient improved, and the left sterno-mastoid recovered its normal tone, she was able to prevent the spasm by constantly keeping the right sterno-mastoid at a *mechanical disadvantage.* At first the head was kept twisted very much over to the right, so that with an imaginary line connecting the two mastoid processes of the skull, the right sterno-mastoid muscle formed an angle more acute than would have been the case with the chin in the middle line, while the angle included by the same imaginary line and the left sterno-mastoid was more obtuse than would have been the case had the head been carried in its normal position. Gradually, as the patient improved, the difference between the two angles formed by the two sterno-mastoid muscles and the imaginary line got less and less, and at present there is scarcely a degree to choose between them.

At first the head was invariably jerked over to the left the instant that the chin was allowed to approach the middle line. Now, however, spasms are of very rare occurrence, and only occur 'when she is flurried.' With *the head in any position* she is now able, 'by taking thought,' to prevent the occurrence of the spasm.

Acting upon this theory, the first indication in treatment was to remove the cause, and the patient was accordingly enjoined on no account to do any hand-sewing again, although she has been permitted to work a little with the sewing-machine. Secondly, it was attempted to restore the fatigued muscles to their healthy condition, and the continuous current has admirably fulfilled this object; its great potency as an anodyne removed the pain; it suppressed the spasm during the period of its application, and it probably increased the afflux of blood to the muscles. The opportunity of subjecting the muscles to regular rhythmical exercises, at the only time when such exercises were possible, being taken advantage of, their perverted nutrition was speedily restored to its normal state, and the patient rapidly improved.

Case XXVI.

Clonic torticollis treated by franklinism (*Guy's Hospital Reports*, 1841).

Henry Mason, aged 40, an out-patient at Guy's Hospital under Dr. Bird; a fine, stout, and healthy-looking man, engaged until lately as a country traveller for a large commercial house. He has lived freely, and has been exposed to frequent and sudden alternations of temperature. About eight years ago, during an extremely cold night in a severe winter, whilst driving in an open country in a gig, he was nearly frozen to death; and shortly after recovering from the partial stupor in which he was found, was seized with an involuntary spasmodic motion of the muscles of the right side of the neck. After an illness of nine months he recovered completely. Within the last four months this affection has returned, and at present he presents the following appearances. Every few minutes his head is turned, with a jerking involuntary movement towards one side, with such force and to such an extent as to threaten strangulation, the vessels of the face and neck becoming extremely turgid. In a short time the spasm ceases and the head moves back to its ordinary position, being, however, in a few minutes carried to the opposite side. These motions he is obliged to control by seizing hold of his nose, using it as a lever to keep his head steady; and, in fact, he usually walks about in this position or with his arms raised, so as to seize hold of the nose on the accession of the involuntary movement. On the slightest excitement, these motions increase to a distressing extent; they are absent during sleep. He was ordered sulphate of zinc, which he took during several weeks; the dose being carried to eight grains thrice a day without relief. The different functions of his body appearing to be tolerably well performed, with the exception of a tendency to constipation, he was ordered an occasional dose of the Pulv. rhei salin.; and sparks were taken on alternate days from the spine and along the sterno-mastoid muscles. He commenced this treatment early in December 1839.

'Dec. 13. He is considerably improved, and can walk without using his hand to steady his head, unless considerably excited.

'Feb. 20, 1840. He has continued gradually to improve, until a fortnight ago; when, considering himself tolerably well, he ceased to attend, and indulged in intemperance and general irregular habits. On coming this day to the hospital he was much worse, the involuntary movements of the head and neck having increased. Electricity was again ordered, and in a short time he became convalescent.'

Case XXVII.

Spasmodic wry neck excited by fatigue (*Guy's Hospital Reports, Dr. Gull*, 1851).

W. W., æt. 50, a thin, pale, and nervous woman, had, for some time previous to the distortions of her head to one side, been troubled with an uncomfortable sensation of weakness and pain in the opposite shoulder, which was greatly increased by fatigue. She attributes her symptoms to having overtired her arm by carrying a heavy basket of china. The spasm (of the mastoid muscle) did not follow for near six months afterwards, but she connects the two together, from having, after the fatigue, felt an occasional pain about the neck. She obtained no relief from electrical or other treatment.

In the volume of the Guy's Hospital Reports for 1837, will be found an interesting paper by Dr. Addison on the use of electricity in convulsive and spasmodic diseases. The franklinic form of electricity was employed either by 'taking sparks' along the course of the spine or by sending shocks through the pelvis. When it was desired to take sparks from the spine 'the patient was seated on an insulated stool, and a metallic connection made between the prime conductor of the machine and the body of the patient: a brass ball furnished with a wire or chain was then passed upwards and downwards in the direction of the spine, at a distance of about an inch from the surface. The machine being at this time excited, the patient became charged, and the electricity continued to pass off accompanied by sparks to the brass ball, and thence escaping through the medium of the wire or chain, to the earth. In this manner a rapid succession of sparks could be maintained: and which in the present instance was continued until an eruption followed, which assumed very much the appearance of lichen urticatus; the time necessary for its production varying in different patients from five to ten minutes.'

The shocks through the pelvis were sent by means of a

Leyden jar. Dr. Addison records six cases of chorea and one of hysterical paralysis, all of which were presumably benefited by this mode of electrical treatment.

Case XXVIII.

Chorea.—This case was one that, in the words of Dr. Reynolds, 'having suffered many things of many physicians, was none the better, but rather the worse,' until Dr. Addison employed electricity. She was 17 years old, and was admitted to Guy's Hospital on May 14, 1837. The menstrual flow had suddenly ceased two months previously, and hysterical fits and chorea supervened. The case was a bad one, the hysteric and choraic elements being both unusually developed. She was treated with bleeding, blisters, strong purgatives, and creasote. Her symptoms became aggravated. Purgatives, camphor, prussic acid, sulphate of zinc, and hyoscyamus were next tried. 'Not the slightest abatement occurred in her symptoms.'

Menstruation however resulted. Then recourse was had to 'cupping over the loins,' blisters along the spine, and 36 grains of sulphate of zinc daily. Not the slightest abatement took place. Dashing of cold water over the head and along the spine was next tried. This had to be discontinued in consequence of an attack of bronchitis, which, however, soon yielded 'under depletion and mercurials.' The former remedies were then vigorously applied till June 15, when the zinc was replaced by carbonate of iron, for which a week later the sulphate was substituted. She took 32 grains of sulphate of iron daily, 'assisted by purgatives, chiefly of calomel and compound extract of colocynth, or aloes and myrrh, and the use of the shower bath.' She very much improved, and left the hospital on August 15. On October 15 she again appeared in a much worse condition, epileptiform attacks and hysterical coma having replaced the chorea. There had been no return of the catamenia since May. She was now subjected to drachm doses of carbonate of iron, shower baths, blisters, and 'drastic purgatives becoming necessary croton oil was given.' On October 20 the sulphate of iron was substituted for the carbonate, and it became necessary on one occasion, in order to rouse her from a fit, to give 'repeated assafœtida injections,' which brought away large quantities of fæcal matter tinged with iron. Camphor, valerian, and sulphate of zinc were next given, the dose of the latter gradually rising to thirty-six grains a day, 'added to which was the ferri sulph.' The chorea returned, and the epileptic fits numbered two or three daily. 'In this state she continued many months, with perhaps some alleviation of the epileptic attacks, but no improvement in the chorea.' 'As a last resource, Dr. Addison ordered electricity.' The first application was on April 20. On May 10 she could use her needle, and in another week she could walk without assistance. On June 1 twelve shocks through the pelvis every other day were ordered. The first application produced a catamenial flow. On July 3 a similar application was again followed by menstruation, and on July 15 she left the hospital 'entirely free from chorea, though still subject to fits of diminished force and frequency.'

Of Dr. Addison's remaining five cases of chorea, one was a male aged 14, and the other four were females, aged respectively 14, 21, 16, and 12.

Of the females two were severe cases, and all of them improved far more rapidly after than before the application of electricity. In three out of the six female cases recorded in this paper it is mentioned that the catamenial flow followed close upon the application of electricity.

In the volume of the same reports for 1841, the report 'On the value of electricity as a remedial agent,' is pursued in a very able paper by Dr. Golding Bird. Thirty-six cases of chorea are reported, all of which were either cured or relieved, and it is stated that in very many of the cases 'every variety of treatment had been tried before the patients were admitted into the electrical room of the hospital.' All the cases were treated by static electricity, in the same way as Dr. Addison's patient. Dr. Golding Bird makes the following interesting observation in summing up his conclusions:—'From the results of the cases treated at Guy's Hospital, no doubt can remain on the mind of anyone that electricity really exerts a decided, not to say specific, influence on these affections. . . . As I feel extremely unwilling to recognise the existence of more specific remedies than necessary, I would venture to suggest that electric sparks, when drawn from the spine, may act by the irritation they produce; and this appears countenanced by the fact that the rapidity with which the patient's symptoms are relieved is nearly in a ratio with the facility with which the peculiar papular eruption makes its appearance.'

We have given one of these cases in detail, because it exemplifies the wonderful change which has taken place in our mode of treating such cases. According to our present notions, the treatment pursued by Dr. Addison would be more likely than not to increase the disturbance, and it is quite open to question whether the cessation of heroic measures may not have been productive of as much good as the adoption of electrical treatment.

It is seldom that cases of chorea in the present day require much treatment of any kind, and we rarely see cases which do not yield to mere hygienic regimen; but, nevertheless, it is difficult, in the face of Dr. Addison's and Dr. Golding Bird's testimony, not to credit franklinic electricity with some share in the cures recorded. Dr. Wilks, in a lecture recorded in the 'British Medical Journal' (vol. i. 1873), says, 'After the introduction of electro-magnetism or faradisation, frictional electricity fell into disuse; but I feel confident that it was not successfully superseded by the new method. For instance, the application of the faradic current to the back was not productive of the same good effect as the withdrawal of the sparks from the same region of the body.'

Sir William Gull, in his report (1851), confirms the experience of Drs. Addison and Golding Bird, as to the usefulness of franklinic electricity in chorea. He says, 'The fact stands well established, that electricity is at present to be ranked amongst the means at our disposal for the cure of chorea, and that in severe cases its effects are often truly surprising. Where other means cannot be employed; when the patient is scarcely able to swallow; where the skin is abraded from the prominent bones of the emaciated frame; when the powers of life seem nearly exhausted, sparks of electricity drawn from the whole length of the spine will often, after a few repetitions, effect a favourable change, and enable us to administer other means of cure.'

Twenty-five cases are recorded, nearly all of which were either cured (nineteen cases) or improved (five cases). Only one case is recorded as 'not cured.'

CHAPTER VIII.

ELECTRICITY AS A CAUSTIC.

THE writer is aware that the subjects upon which this and one of the subsequent chapters treat, belong to the domain of surgery, rather than that of medicine; but, with the desire of not leaving the reader uninformed on any of the more important applications of electricity, he has been unwilling to leave them unnoticed. He must, however, ask for some indulgence from the reader while discussing matters with which physicians do not habitually deal.

The chemical effects of the galvanic current have been largely employed, both by surgeons and physicians. If two platinum electrodes, in connection with a battery, be immersed in distilled water, very little effect is produced. If, however, a little salt be added, rapid decomposition of the water ensues. Bubbles of gas are evolved at either electrode, and it is observed that the gas which is evolved at the negative electrode, exceeds in amount that which is evolved at the positive electrode. The gas evolved at the negative electrode is hydrogen, while that evolved at the positive is oxygen.

If a solution of any conducting binary compound be subjected to this decomposing action of the galvanic current (called electrolysis), it is resolved into its component ingredients. When, for example, a solution of potassium iodide is electrolysed, the potassium goes towards the negative pole, where it decomposes the water, uniting with the oxygen to form potash, while the hydrogen escapes. The iodine is deposited at the positive pole.

When salts of the alkalies or earths are decomposed in the same way, the earth or alkali goes to the negative, and the acid to the positive pole. With sodium sulphate, the decomposition is supposed to be affected in this way. The salt (Na_2SO_4) is first decomposed into sodium, which goes towards the negative, and into sulphion (SO_4), which goes towards the positive pole. The sodium decomposes the water, combining with the oxygen to form soda, the hydrogen being liberated. The sulphion likewise decomposes the water, uniting with the hydrogen to form sulphuric acid, the oxygen being liberated.

If the positive electrode be formed of an oxidisable metal such as copper, it first oxidises and then unites with the acid liberated in its neighbourhood. Thus, with sulphate of soda, we should first get oxide of copper formed, and subsequently the sulphate.

If a solution of chloride of sodium be electrolysed with zinc electrodes, chloride of zinc will be formed at the positive pole. We have elsewhere remarked, that it is probably impossible to pass a galvanic current through animal tissues without setting up some electrolytic action, and we are unable to say what part such action may play in the ordinary phenomena caused by the galvanic current. It has been frequently insisted upon, that the negative pole of the galvanic battery is to be used with great caution, because of its irritating effect.. It causes redness of the skin far more readily than the positive pole, and if it be allowed to remain stationary, vesication and even ulceration will result. This result is probably due to the liberation of free alkali in its neighbourhood, and may be directly compared to the application of caustic soda or potash to the part. Patients who wear galvanic chain batteries continuously applied to the body invariably get very troublesome ulcerations at the negative poles, and the amount of this ulceration may be looked upon as a rough gauge of the strength of the galvanic current to which the battery has given rise. The author has become quite familiar with these 'galvanic scars,' and he has seen one patient whose chest, back, neck, and arms were literally covered with them.

Dr. Althaus has given this subject very particular attention, and the reader who desires further information cannot do better than consult his work on 'Medical Electricity.' He says: 'In 1866 and 1867 I made a series of microscopical observations on the changes which animal structures undergo under the influence of the electrolytic action of the galvanic current. . . The general result of these investigations has been that *no animal tissue whatever can withstand the disintegrating effect of the negative pole, and that the force and rapidity with which this disintegration is brought about are directly proportional to the electromotive force which is employed, and to the softness and vascularity of the structures acted upon*. . . A curious and novel circumstance forced itself early on my attention; and this was, that the electrolytic effect of the negative pole on animal tissues was mainly composed of two different elements, viz. of the mechanical action of the nascent hydrogen, which was under the microscope seen to rise in innumerable bubbles as soon as the circuit was closed, and to force itself, as it were, between the structural elements of the tissues, driving their fibres mechanically asunder; and, secondly, of the chemical action of the alkalies, soda, potash, and lime, which, together with hydrogen, are developed at the negative pole of the battery. . . . The immediate effect of the electrolytic decomposition of any animal liquid is, that the anode is oxidised and chlorinated, and from a metal changed into a metallic salt. . . On the other hand, metals are not changed by hydrogen or free alkali, and the cathode, therefore, retains its bright metallic aspect; whatever may be the power of the current used, or the length of time during which the action is kept up. In using the cathode, therefore, we do not introduce any foreign substance into the liquid, but only alter its composition; while, by using the anode, we may introduce into it salts of iron, copper, silver, gold or any other metals used as directors and which combine with the albumen to form albuminates.'

When a zinc needle is used, we get salts of zinc formed at the anode, and the caustic action of these salts has often a more powerful effect than the alkali liberated at the negative pole.

'Galvano-caustique Chimique' is the name given by Tripier to the electrolytic action of the current when employed for the purpose of destroying tissue. He says, 'When an imperfectly conducting body, capable of decomposition, is placed in the circuit of a battery of sufficient power, it is decomposed: acids going to the positive, alkalies to the negative electrode. . . The acids and alkalies generated act upon the tissues in the manner of potential caustics, causing the appearance of eschars exactly limited to the points covered by the electrodes. One can thus cause, wherever the finest stylet can penetrate, cauterisations like those caused by the action of acids or alkalies, and whose activity is easily regulated by attention to the quantity and tension of the current employed. . . Ciniselli had noticed that the eschars produced at the two poles offer sensibly different appearances. Before having remarked this difference of the eschars succeeding to the application of acids and alkalies, a difference known of old, and which had served to divide potential caustics into acids or coagulisers and alkalies, or fluidisers, I had been struck with the difference of the cicatrices to which the eschars give rise, and had recognised the fact (since confirmed by histological investigations) that the acid cauterisations give rise to hard and retractile cicatrices, while the alkaline cauterisations give soft cicatrices, which are little or not at all retractile. These observations led me to abandon *positive* cauterisation for all general purposes of cauterisation, and to pursue especially the applications of the *negative* cautery useful in the numerous cases where the deliquescence and want of consistence of the alkaline cauteries had caused them to be preferred to acids, the actual cautery, the acid galvanic cautery, or non-interference. These cases are those in which it is of importance to get soft and non-retractile cicatrices in parts difficult of access or on which one cannot act chemically without exposing the neighbouring tissues to more or less injury. . . When one of the electrodes is used for cauterising, the other serves only to close the circuit. To avoid useless cauterisation at the position of this latter, I have caused it to terminate in a large button of carbon separated by one or more layers of moist agaric from the cutaneous surface on which it is employed.'

Tripier has successfully employed this mode of cauterising

1. In cases of ulcerations of the os tincæ invading the canal of the neck of the uterus, and also to re-establish the permeability of the internal orifice of the canal in cases where it seemed to be almost entirely obliterated.

2. For removing lipomata by superficial cauterisations.

3. For opening buboes (the negative electrode being of the form of a linear fish-bone cautery).

4. In cases of obliteration of the nasal duct.

5. In the removal of hæmorrhoids and condylomata, electrodes of special forms, resembling clamps or nooses, being used.

6. For stricture of the urethra. A great number of operations performed by MM. Mallez and Tripier in the last eight years, as well as by other surgeons, on strictures, some of which were impassable, have, according to M. Tripier, established the efficaciousness and harmlessness of the procedure which has been accompanied by a permanence in the results such as no other method of treatment has given.

7. For stricture of the rectum.

When we wish to get the caustic effect of the current, it is usual to apply the negative rheophore of small surface to the part upon which the caustic action is desired, or insert it into the tissues while the positive rheophore of large area is applied to the surface of the body.

The assertion made by Tripier that the cicatrices of eschars caused by alkalies or by the negative pole of the galvanic battery are not liable to contract, seems to us to stand in need of confirmation. Apart from the question of the specific action of acids or alkalies, it is certain that the negative pole has far more cauterising power than the positive, and the author has noticed that eschars formed by the negative electrode are remarkably slow in healing. He is not prepared, however, to say that the cicatrix once formed is less prone to contract than any other form of cicatrix. That the action of caustic alkalies on the alimentary canal not unfrequently results in fatal stricture is an acknowledged fact, and in Taylor's 'Principles of Medical Jurisprudence,' p. 232, the reader will find the record of a case of poisoning with a concentrated solution of carbonate of potash, in which the victim survived two months, and in which, at the post-mortem examination, in addition to other injuries, the intestinal end of the stomach 'presented a large and dense cicatrix, obstructing all communication with the small intestines, except by an orifice no larger than a probe.'

The surgeon will have to decide, in cases in which the application of caustics seems to be advisable, whether or no he will make use of the caustic action of electricity. The obvious advantages of electricity over other caustics are the following:

1. It may be applied with safety to regions (such as the larynx and pharynx) in which the application of other caustics must be attended with a certain amount of danger.

2. The caustic action, both as regards the time of commencement, the intensity, and the duration, is absolutely under the control of the surgeon.

3. By employing partially insulated needles, it may be applied to subcutaneous tissues while the skin itself remains uninjured.

If the tissues upon which we wish to exert a caustic action are of considerable bulk, such as a tumour, it is not unusual to have several needles connected with the negative pole, and in this way we get a caustic action set up throughout the whole mass of the growth.

It is often advisable to insert both rheophores into the growth (such as a nævus) which we wish to destroy. In this way a far more intense action is insured, since the current has not to encounter the great resistance of the epidermis.

Nœvus.—In the 'Lancet' for March 20, 1875, Mr. S. J. Knott, the medical superintendent of galvanism to St. Mary's Hospital, speaks highly of the treatment of *nœvus* by electrolysis. He records forty cases successfully treated in this way, the advantages claimed for which are 'its certainty of action, its safety, the faintness of the cicatrix, and the cessation of pain directly the operation is over.' Mr. Knott employs six or eight cells of a zinc carbon battery, and, according to the size of the tumour, passes two or more needles connected with the negative pole into the nævus, while the positive pole is represented either by one needle passed into the nævus, or by a charcoal point applied to its exterior. 'After the needles have been in the tumour a short time, decomposition begins to take place; this is shown by bubbles of gas passing by the side of the needles. A clot is then formed, the tumour turns of a bluish white, and in this clot fibrous degeneration takes place, and ultimate cure is the result.'

Hydrocele.—Dr. Rudolfi, of Brescia, has treated hydroceles by first tapping and then passing into the sac a copper probe (connected with the negative pole of a galvanic battery), which is made to touch the internal surface of the sac. The positive pole, in the form of a moistened sponge, is applied to the surface of the scrotum.

His method consists, in fact, in applying an alkaline caustic to the internal surface of the sac.

Dr. Rudolfi records eight cases treated in this manner. Of these three were radically cured; two required a repetition of the operation; one was not cured, but would not submit to a further operation, and in two drainage was required to complete the cure.

The operation was attended by no small amount of pain and swelling, and in one case suppuration resulted.

Of the successful cases (1) was under treatment a month, (2) was under treatment for two periods of one month and two months respectively (in this case drainage was necessary), (3) was under treatment for three months, (4) for twenty-three days, (5) for two periods of eleven days and two days respectively, (6) for a month, and (7) for two periods of one month and five weeks respectively.—'London Medical Record,' June 25, 1873, and September 2, 1874.

These results are certainly not such as to cause this mode of treatment to be generally adopted.

Hydatid Tumours of the Liver have been treated by galvano-puncture, and some interesting details of cases have been published by Mr. Durham and Dr. Hilton Fagge. Two needles in connection with the negative pole were passed into the cyst while the positive was applied to the surface of the abdomen. On closing the circuit the crackling noise caused by the escape of hydrogen was audible. Eight successful cases were recorded, and in no instance did suppuration result. Recent experience, however, makes it doubtful whether simple acupuncture without electricity is not an equally efficacious method of treating these cysts, and a recent paper by Dr. Duffin, in the 'Transactions of the Clinical Society' for 1873, shows that tapping with a fine trocar is probably quite as successful as galvano-puncture or simple acupuncture.

Naso-pharyngeal Polypi.—Dr. Bruns ('Berliner Klinische Wochenschrift,' Aug. 11, 1873) records cases of successful treatment of *Naso-pharyngeal Polypi* with electrolysis. He considers that his cases, though few, have been so successful 'that in future this method will be tried before proceeding to a more serious operation. There is no risk of bleeding, and no danger; and a relapse is considered less likely, inasmuch as, when the operation is successful, it must be complete, whereas in removal by other plans one is very likely to leave some portion of the insertion of the tumour still remaining attached.'

Case XXIX.

Naso-pharyngeal Polypus.—This patient was a man æt. 30. His sufferings had commenced at sixteen, and the left side of the nose was soon blocked up. At eighteen a tumour of the size of a walnut was removed through the mouth, but it grew again. At twenty-two another operation was undertaken. The nose was split up the middle as far as the bone, but only a small portion of the tumour was removed, and the operation was without result. Since then the inconvenience increased, respiration, speech, and hearing were interfered with, and during the last three years there were ten bleedings, some of a very serious nature, from the tumour. The tumour filled the posterior nares, pressed down the soft palate and was visible through the mouth. It had the appearance of the so-called fibrous polypus.

The needles were of zinc; one was introduced through the right nostril into the tumour, and the other was passed by the mouth. The needles were passed through an aural catheter of vulcanised india-rubber so as to protect the mouth and nostril. The duration of the sittings varied from ten to twenty-five minutes. During the time, considerable pain was felt in the tumour and a metallic taste in the mouth, and the crepitation of the gas which was formed could be distinctly heard. The tumour partly rolled down and was partly absorbed. After eleven applications with intervals of from four to ten days the patient went home. Four weeks afterwards he presented himself. The tumour had completely disappeared, and on rhinoscopic examination it was easy to recognise a cicatrix on the right side of the basilar process, close to the septum narium, which was evidently the place from which the polypus grew.—'London Medical Record,' October 1, 1873.

By the use of zinc needles, Bruns was enabled to apply potent caustics to the tumour. Alkalies being liberated at the negative pole probably exerted a caustic action, while the chlorides in the tissues would convert the positive needle into chloride of zinc, which also exerted its powerful caustic effect upon the point of origin of the polypus. The 'secondary electrolysis' is the important element in this treatment of Bruns, which consists in reality in an application of chloride of zinc to the parts.

Dr. F. Fieber, of Vienna, calls attention to the advantages of electrolysis over all other methods for removing tumours of the larynx, especially in the hands of those who have not had much special practice in the manipulations of laryngeal surgery.

In a paper on 'Electrolysis,' in the 'British Medical Journal' for February 10, 1872, Mr. Callender records some of his experiences at St. Bartholomew's Hospital, and he thus sums up his opinion: 'My belief thus far is that in no instance has the progress of the tumours been visibly influenced by the use of the current, in the sense of its causing wasting or shrinking of the growth, independently of the cauterising action. It always seemed to me that, with the exception of some heat and tenderness, no change was produced when a current of from six to eight cells was employed, the electrodes being separated by some little interval of tissue. . . . With regard to the cauterising effects of the continuous current, there is, however, no question that we have a powerful and valuable remedy. With twelve cells (of Stöhrer's zinc carbon battery) and using two needles, the one at the positive and the other at the negative pole, small growths . . . . were rapidly destroyed without complaint of pain on the part of the patient, and, what is more, were destroyed so effectually that the skin healed over the parts of the granulating surface from which they were growing. For the cauterising of such recurrent masses, especially for that of the small nodules which spring up about the scar tissue after removal of a cancer growth, and which, if allowed to increase, necessitate for their removal a considerable operation, the continuous current seems to offer a handy and efficient remedy.'

Groh, Professor of Clinical Surgery at Olmutz, writing on electrolysis of tumours, says he uses zinc needles, and thus gets a secondary action by the production of chloride of zinc, and an eschar forms similar to that made by chloride of zinc paste. The disengagement of gas causes distension of the parts, discoloration, and sloughing.

The advantages are: 1. No hæmorrhage; 2. Very slight general reaction; 3. Eschars soon thrown off. Groh has used this method for large tumours of lower jaw, epithelioma of lip, and cancer of rectum.

He is in the habit of using the galvanic current in two different ways: (1) a powerful current employed for a short time, and (2) a gentle current employed for a prolonged period. He records, among others, the case of a myxo-sarcoma of the leg, upon which he acted with a weak current from Daniell's elements for seventeen days, at the end of which time suppuration supervened, and the patient was discharged cured.

He has also found electrolysis very useful in lessening the pain of certain cancerous and other tumours, and in this his experience accords with that of most surgeons who have given this method a trial. ('London Medical Record,' March 5, 1873.)

CHAPTER IX.

ELECTRICITY IN THE TREATMENT OF INTERNAL ANEURISMS.

In the last chapter we considered the electrolytic action of the galvanic current as applied to the solution of animal tissues; in the present chapter we shall deal exclusively with the effects of electrolysis upon the blood. Before considering the effect of the galvanic current upon the blood it will be well for the reader to make himself familiar with its action upon albuminous fluids. If two steel needles connected with the poles of a galvanic battery be immersed in some white of egg contained in a glass, the following phenomena will be observed:—Around the positive needle a firm white clot is formed; at the negative needle bubbles of hydrogen escape, and a loose pseudo-clot is formed resembling 'whipped cream' in appearance and consistence. These clots continue to increase in size as long as the circuit is closed. On removing the needles from the fluid, the positive clot will be found to adhere more or less firmly, and to be acid in reaction; the negative clot will probably slip off the needle, and it will be found to be alkaline in reaction. On examining the needles the negative will be found as smooth and polished as when it was immersed; the positive needle will be found corroded, the corrosion bearing an exact proportion to the duration and intensity of the current and the size of the positive clot. The positive clot will be found slightly tinged with red, from contamination with the chloride of iron, which has been formed at the positive pole, and to the action of which salt much of the clot is doubtless due. It is important to bear in mind that when corrosible electrodes are used for electrolysis, the corrosion of the positive pole is a necessary consequence.

With regard to the action of electrolysis upon the blood we know very little. Professor Lister's experiments have shown that the mere contact of a foreign body, such as a needle, is sufficient to bring about coagulation; and when, therefore, clots are formed round electrodes it is generally impossible to say how much of the coagulation is due to electrolytic action, and how much is due to the mere contact of the electrodes with the blood.

Dr. Duncan and Dr. Fraser electrolysed blood contained in a glass globe. The whole of the blood in the globe was quickly transformed into a big clot. A section was made through the globular clot at the points where the electrodes had entered it. It was found that the electrolytic clots extended an inch into the mass, in a conical form. The negative had a diameter of 0·75 inch at the surface or base, and had a markedly alkaline reaction. The positive was 0·5 inch at the base, and was strongly acid. Both clots were perfectly distinguishable from the normally coagulated blood, and both possessed greater consistence and tenacity than it.

The best method of determining the actual effect of electricity upon blood-coagulation would probably be to imitate the experiments of Professor Lister, and operate upon the blood while it is still in contact with the fresh animal tissues. The jugular veins of horses removed from the body are found capable of maintaining the fluidity of the blood contained in them for many hours, and properly conducted experiments on blood contained in fresh jugular veins might serve to elucidate the different effects of galvano-puncture and simple puncture, of which as yet we know but little. Even, however, with experiments like these we should still be uninformed as to the part which the movement of the blood (such as occurs in aneurismal sacs) plays in producing coagulation.

Dr. John Duncan, writing on the 'Surgical Applications of Electricity,' states that—

There are three products of the electrolysis of blood: 1. A moderately firm, black dryish clot which surrounds the positive needle; 2. A quantity of gas which, in the shape of fine froth, surrounds the negative; 3. A fluid of the consistence and appearance of thin tar. The tarry fluid is a trouble in the treatment of aneurism, and Dr. Duncan thinks its accumulation may be obviated by employing a very weak current, and allowing the tarry fluid to mingle with the circulation as soon as formed.

Ciniselli was the first to study in a scientific manner the coagulating power of the galvanic current when passed through blood contained in an aneurismal sac; and in consequence of the success which 'galvano-puncture' has had in his hands it has during the last few years been frequently practised. In reviewing this mode of treatment, we have to consider: 1. Whether it is worthy of trial; and if so, 2. When we should use it; and, lastly, 3. How we should use it. The first question shall be answered by one who has devoted much attention to the subject of aneurisms in its entirety.

Mr. Holmes, in his lecture on the surgical treatment of aneurism, thus speaks of the method of treatment by galvano-puncture ('Lancet,' Sept. 7, 1872):—

'Experience has shown that this electric action, this coagulation of the mass of the blood in which there is no mechanical separation of the fibrine from its other constituents, is capable of producing the total and final cure of an aneurism. An additional proof, if an additional proof were required, that the slow method of coagulation, by which what Broca denominated "active" clot is generated (*i.e.* the fibrine separated from the other constituents and deposited in laminæ), is not the only, though it may be the safest, way of curing an aneurism.'

'We must admit, further, in forming an estimate of the value of electricity, that the coagula formed by it appear very frequently not to be stable, but to be liable to melt down again into the blood stream. At any rate, it seems a frequent phenomenon in this method of treatment to find an aneurism cease to pulsate for a time, and the pulsations to recur very shortly afterwards. . . . On the other hand, there have been cases in which the coagula produced by electricity seem to have been as stable as those formed naturally. This seems to me not so much an objection to the method in itself as a proof that we do not as yet know enough of its detail. The uncertainties and ambiguities referred to appear to me, however, to be a rational and proper ground for discarding electro-puncture—at any rate, in the present state of our knowledge—in cases of external aneurisms situated on accessible arteries, where the ordinary processes of pressure and ligature offer safer and more reliable means of cure. But no one can have read the literature of this subject, even if he has had no personal experience of the method, without convincing himself that by appropriate manipulation coagula may be produced, in the part of the sac which is operated upon, without any grave inflammatory reaction, or any very serious risk of hæmorrhage, of embolism, or of gangrene opening into the tumour.'

Speaking of its application especially to aortic aneurisms, Mr. Holmes says: 'Considering the numerous instances of spontaneous cure of aneurisms of the thoracic aorta which have been put on record, considering that many of the aneurisms of this artery are sacculated, communicating with the trunk by a comparatively narrow opening, and considering that, in some cases at any rate, aneurisms of this kind grow forwards, and do not appear to show any disposition to press on or ulcerate into the neighbouring viscera, I see no reason to doubt that in some proportion (hitherto undetermined) of aneurisms of the thoracic aorta a radical cure by rapid coagulation of the blood is possible. For if we allow that aneurisms of this artery are curable at all, and if we allow that galvano-puncture is capable of producing complete coagulation in an aneurismal sac, how can we deny the theoretical possibility of thus curing an aortic aneurism?'

Mr. Holmes points out that an aortic aneurism protruding forwards often consists of two parts—'the one lying within the thorax ("primary intra-thoracic aneurism" in Ciniselli's nomenclature), communicating with another great sac external to the bony walls of the chest ("secondary external" of the same author).'

Now 'a large external sac, with a comparatively small communication with the thorax, is an unfavourable condition for electro-puncture. It must be remembered that the clot formed by electrolysis is much softer and less stable even than the natural blood coagulum, being mingled with much gas formed by the decomposition. It requires, therefore, some amount of circulation in order to consolidate it, and is more to be regarded as a nucleus for future coagulation than as itself the obliterating medium. The consolidation, therefore, even of the whole external sac, would not tend in any perceptible degree to check the progress of the internal aneurism. . . . Therefore an aneurism is best adapted for this treatment when it is pressing on the parietes, but has not absolutely perforated them. Again, the sacculated condition of the aneurism and the relative smallness of the opening are essential conditions for a case which is to be looked on as really favourable.'

Aneurisms of this latter kind generally (but not always) have a distinct bruit, which may be looked upon as a symptom favourable for electro-puncture.

The cure effected by galvano-puncture is rarely complete and permanent, but serving, as it does, to check the growth of the tumour it gives the patient a better prospect of the natural or medical cure. 'Even allowing that the disease will almost certainly burst out again, yet the question will occur in this as in other surgical operations undertaken to stay the progress of diseases which are almost certain to prove fatal at last, whether the respite is obtained at too great a risk or no. If not, the same considerations as justify the amputation of a limb or a testicle or a breast for cancer, which we believe will ultimately recur, will justify this operation also, and all the more since the disease threatens to end more speedily.'

Signor Ciniselli, who may be said to be the champion of this method of treating aneurism, thus temperately sums up its advantages :—

'We must not exaggerate the value of this method. The circumstances which are favourable to a perfect success occur very rarely in practice. In the majority of cases which present themselves the disease is in too advanced a condition, and should not be operated upon, because the operation will be useless and perhaps mischievous. In the cases where the most favourable conditions exist it may be possible to obtain consolidation and cure of an idiopathic aneurism ; but since the cause which produced the aneurism—viz., an atheromatous condition of arteries—still exists, as this increases it causes a recurrence in another part of the vessel. Admitting this, however, considering that we are dealing with a malady for which up to the present time no surer remedy has been discovered, I sumbit that it is a considerable step in the treatment of internal aneurisms to have discovered a method which, employed according to the rules sanctioned by experience, proves innocent, procures a cure, even if temporary, alleviates the patient's sufferings, and prolongs his life.'

Ciniselli ('Il Galvani,' Jan. 1873) concludes from four failures, that when large trunks issue from an aneurismal sac, galvano-puncture is useless. Even the fifth case only prolonged the man's life from May to September.

We are now in a position to answer two out of the three questions which we have proposed :—

1. The operation of galvano-puncture is admissible in certain cases.

2. It must be employed—

(*a*) For internal aneurisms only, and

(*b*) For such as are not too far advanced. Those are the most favourable in which the sac presses upon, but has not perforated the parietes. A large external sac is a decided contra-indication. Sacculated aneurisms having moderately small openings indicated by a distinct bruit, or still better by a double bruit, are the most favourable for operation. The origin of large trunks from the sac of an aneurism is a contra-indication.

We have next to consider the best method of operating. First, as to the form of electrode which is to be inserted into the aneurismal sac. All are agreed that steel needles are the best. They should be sharp and carefully polished, so as to go with ease through the integuments; and since we wish to avoid exerting any electrolytic action upon the integuments themselves, the shafts of the needles should be carefully insulated with vulcanite or gum-elastic. Sometimes a mere coating of varnish has been used as an insulator, but it is doubtful whether this is sufficiently reliable. An excellent needle is made by Messrs. Weiss, consisting of a fine spear-headed steel shaft insulated by gum-elastic. The needle cannot be too fine, if only it be strong enough to pierce the walls of the aneurism without risk of rupture. In his early operations Ciniselli employed needles which were not insulated in the shaft; and in order to avoid as much as possible the caustic action of the liberated acids and alkalies upon the skin he connected no needle with the negative pole until it had first been in connection with the positive pole, and thus the liberated alkalies were neutralised by the previously liberated acids. In order, too, to mitigate the caustic effect at any one spot, he was accustomed to employ six needles, which were all passed through different parts of the sac, and placed in connection with either pole of the battery by turns. If, however, the needle be perfectly insulated, a current may be passed through it for any reasonable time without fear of injuring the integuments, and therefore there can be no sufficient reason for increasing the number of needles beyond two.

It has been recommended to introduce two needles into the sac, and connect one with the positive and the other with the negative pole. This seems to the author the most desirable way of proceeding. Only in this way can we be sure of exerting any real electrolytic action upon the blood. In this way we reduce the resistance to the current to a minimum, and we are able to produce adequate effects with currents which cause the least possible pain and annoyance to the patient. Mr. Marcus Beck and the author have experimented by causing the electrolysis of white of egg held in the palm of the hand, and it has been found that if both electrodes be immersed in the fluid it is easy to produce an amount of coagulation with a very slight current, which is not approached in amount by the most painful currents that can be borne, if passed through the body. The resistance offered by the epidermis is so great as almost entirely to check electrolysis with any currents of bearable strength. If one pole only be introduced into the sac, it must be the positive; and on this point almost all are agreed. The objection to inserting the negative pole is the gas which is liberated in its neighbourhood; but, as a matter of fact, this gas has not caused any trouble in any case in which both poles have been inserted in the aneurism, and it is highly probable that the gas, as soon as formed, is carried away by the current of the blood and redissolved. In those cases in which the negative pole has been applied to the surface of the body, it has been observed that corrosion of the positive pole has been wanting altogether, or was infinitesimally slight in degree, whereas when both poles have been inserted the head of the positive needle has been almostly completely dissolved, and it must be remembered that the amount of corrosion is a rough gauge of the amount of electrolytic action. If the negative pole be applied, in the form of a sponge, to the surface of the body, and if the current be applied for any length of time, we shall certainly produce redness and vesication, or even sloughing of the integuments. If, therefore, it is thought advisable to insert only the positive pole into the aneurism, the negative pole should not be applied to the aneurismal wall, for irritation of it may cause inflammatory action, and the gravest results; it should be applied rather to some distant part of the body, as the hand, for the resistance of the epidermis once overcome it is of comparatively little consequence what length of moist subcutaneous tissue the current has to traverse.

With regard to the current which is most efficacious, Ciniselli says—

'The electromotor apparatus to be employed must be of the least possible *intensity*, but of sufficient *tension* for the production of the electrical coagula. A current of too great intensity is the cause of local inflammatory reaction; too low a tension does not produce the desired effect; too high a tension is the cause of the formation of sloughs.'

'All elements of small surface and low electro-motor power are to be preferred; on the other hand, all elements of large surface and great electro-motor power (such as Bunsen's and Grove's) are to be avoided. With regard to the tension and chemical powers of the battery, the voltametric test is the best. It must be about so great that the battery produces in five minutes 2-3 cub. cent. of explosive gas by the decomposition of water, acidulated with $\frac{1}{30}$ of its weight of sulphuric acid.'

The author quite agrees with Ciniselli that elements of low electromotor power are to be used, and that their surface can hardly be too small. In this way the pain is diminished to a minimum, and the necessity of placing the patient under chloroform is done away with. He has made experiments with a Pulvermacher's chain battery on the coagulation of albumen, and he found that with a chain of sixty links (*i. e.* a battery of sixty couples of the smallest possible surface) he was able to produce a positive clot weighing nine grains in the course of an hour.

The chain battery, however, is very inconstant in its action, and difficult to manage; but the Foveaux-Smee battery, if furnished with means of regulating the depth of immersion of the cells (see Fig. 11), affords means of using elements which are practically as small as those of a voltaic pile or a chain battery. In the case of aneurism, in which the author, in conjunction with Dr. Green, employed galvano-puncture, a battery of this kind was used, the tips of the elements only being immersed, and although the current was sufficient to completely dissolve the head of the positive needle, no inconvenience was caused to the patient. By employing very small elements the risk of the operation is reduced to a minimum, and it is in the highest degree desirable when practising a manœuvre which may be of doubtful service, to be sure that the result shall be, at the worst, negative, and not positively hurtful.

If currents of this kind be employed they may be continued for an hour or more, without causing either annoyance or danger. The chief danger of the operation consists in inflammation in the sac and sloughing of the punctures, but if the rules given above be adhered to the risk of either is very slight. Embolism has never followed this method of treatment. We may thus sum up our answer to the question, How should the operation be performed ?—

(*a*) The patient should lie in bed.

(*b*) No chloroform need be given, but it is often advisable to give a dose of morphia hypodermically before commencing, and if necessary local anæsthesia may be employed to dull the sensibility of the skin during the insertion of the needles.

(*c*) Two well insulated steel needles are to be inserted in the sac, care being taken that their points do not touch.

(*d*) The best current is that generated from a considerable number of cells of small surface and low electromotor power.

(*e*) The current may be continued for an hour or more.

(*f*) The needles are to be withdrawn with great gentleness, the punctures being immediately covered with lint and collodion.

The author thinks he cannot do better than conclude this chapter with abstracts of some of the chief cases of galvano-puncture which have been reported at length in the medical journals and elsewhere. Such a series of abstracts cannot but prove of service to practitioners who are contemplating this method of treating aneurism. It must be confessed, however, that these reports do not appear very encouraging. In most of the cases, probably, galvano-puncture was too long delayed. The author hopes that, by following the rules laid down for the operation, it may be deprived of all danger, and that in proceeding to employ galvano-puncture for the future we may be tolerably certain of doing no harm, even though no great amount of success may follow.

Case XXX.

Dr. Bastian's Case of Galvano-Puncture ('British Medical Journal,' Nov. 22, 1873).—R. W. F., m., 53.

Probable Duration of Disease.—Possibly ten years. Tumour noticed for two years.

Seat.—Transverse part of arch of aorta. In front of innominate and left carotid.

Size of Sac.—2½ inches in diameter (*post mortem.*)

Orifice of Sac.—1¼ inch in diameter.

The left carotid took origin within the sac.

First Operation.—October 8, 1873. Chloroform given.

Positive Pole.—Hare-lip needle, insulated in the shaft with two layers of varnish, introduced into the sac 'to a depth of ¾ inch.'

Negative Pole.—Large sponge, placed on surface of tumour.

Current.—Five cells of Foveaux's battery.

Duration.—Thirty minutes.

Result.—A systolic bruit, audible after but not before the operation. No corrosion of needle. Pulsation of aneurism not changed. No loss of blood. Puncture healed completely.

Second Operation.—October 13, 1873. No chloroform.

Positive Pole.—As before.

Negative Pole.—As before.

Current.—Eight cells of Foveaux.

Duration.—Thirty minutes.

Result.—Vesication of skin under negative pole. No loss of blood from puncture. Some increase in size of tumour. Puncture healed completely. Bruit continued. No mention made of corrosion of needle.

Third Operation.—October 18, 1873. No chloroform.

Positive Pole.—Two hare-lip needles {
One as before.
The other zinc-coated, not insulated.

Negative Pole.—As before.

Current.—Eleven cells of Foveaux's battery.

Duration.—Not mentioned.

Result.—Some dull aching pain during operation, 'apparently due to the moderately firm pressure of sponge upon the upper rounded end of the swelling.' Erythematous patch and small bullæ under negative sponge. Red circles round needles, and the part immediately in contact with zinc-coated needle was of a dead white colour. No blood lost. The zinc-coated needle was distinctly corroded. The other needle was slightly corroded at its extreme tip. Bruit more marked.

October 19.—Red blush below situation of negative pole. Slight oozing of blood from both punctures.

October 20.—Increase in size of tumour.

October 21.—More redness round the puncture caused by zinc-coated needle than the other.

October 27.—Rigor; febrile symptoms. Temperature 104·6. Irritation round punctures had continued.

October 28.—Enlargement of tumour, due to œdema of integuments. Slight oozing of fluid, first through zinc-coated needle puncture, and then through both. High fever. Dyspnœa.

October 29.—Death.

Post mortem.—The swelling in front of chest had disappeared, with the exception of a small conical eminence, about

$\frac{1}{2}$ inch in diameter, having the right (zinc-coated needle) puncture in its centre. The skin of this region had a reddish purple discoloration, which extended, though to a notably less degree, downwards to the nipple, and thence outwards to the axilla. Small quantity of blood effused into substance of the pectoralis major, about two inches away from the zinc-coated needle puncture, and a smaller amount was found diffused round this part as a centre. Effusions of blood into anterior mediastinum. Aneurismal wall was in part very thin (wafery). The sac contained a conical clot, firm and laminated, $2\frac{1}{2}$ inches long, and $\frac{3}{4}$ inch wide at the base; adherent only at one spot, near the junction of the sac with the aorta. Absorption of part of sternum, clavicle, and first rib. The needle punctures through the sac presented no peculiarity, excepting that just inside the zinc-needle puncture was a small portion of very firm fibrine, "similar in character to the substance of the clot, and of the same diameter as the laminæ of its apex." One inch to the right of this puncture, and two inches below it, were two small openings, through which blood had escaped into the pectoral muscle and anterior mediastinum. A firm thrombus found in left carotid. The left pneumogastric nerve had become softened and discoloured from pressure by the sac.

Dr. Bastian does not consider that the punctures in any way contributed to the increase in the size of the aneurism.

The dyspnœa and fever are attributed to the pressure on the pneumogastric. The immediate cause of death was probably the rupture into anterior mediastinum. The clot found in the aneurism probably had its origin at the zinc-coated needle.

[It is difficult to believe that, during those operations in which no corrosion of the positive needle was observed, any electrolytic action took place. When two needles, one zinc-coated and the other of steel, were inserted into the sac, it is probable that a local and entirely secondary galvanic action was set up. The zinc-coated needle, being non-insulated, would render the action of chloride of zinc on the tissues a necessary consequence of electrolysis. The irritation of the negative pole when applied to the surface was well marked in this case. The origin of a large branch from the sac itself was an unfavourable circumstance.]

CASE XXXI.

Mr. Marcus Beck's Case of Galvano-Puncture ('Lancet,' October 18, 1873).—W. W., m., age 41.

Probable Duration.—Possibly three years, certainly one.

Seat.—Lower part of thoracic aorta.

Size and Character of Sac.—Irregular in shape, consisting of two pouches, extending on either side of aorta. The one to the right $5\frac{1}{2} \times 2\frac{1}{2}$ inches. That to the left extended from between ninth and tenth ribs to the diaphragm, and outwards to the tip of the twelfth rib.

Orifice of Sac.—$1\frac{7}{8}$ inch × $1\frac{1}{4}$ inch.

The external tumour measured 3 inches × $3\frac{1}{2}$ inches, and corresponded with the posterior parts of ninth, tenth, and eleventh ribs on left side. The increase in size of the tumour had been very rapid between August 16 and September 2, 1873.

First Operation.—September 2, 1873. No chloroform. $\frac{2}{3}$ grain of morphia administered hypodermically before commencing.

Positive Pole.—Steel needle insulated with gum-elastic, inserted into sac to a depth of $2\frac{1}{2}$ inches.

Negative Pole.—Needle of similar character, inserted into sac.

Current.—Twenty cells of Foveaux, increased after five minutes to twenty-nine.

Duration.—One hour and twenty minutes.

Result.—No bleeding followed removal of needles. Tumour was more tense, firmer, and impulse less expansile. The point of the positive needle almost dissolved away. Negative unchanged, but the gum-elastic covering had become loose. Tumour not resonant after operation. On September

4th he had an attack of faintness and sudden pain in left hypochondrium. On 6th the tumour began to increase in size. On 9th it was found that the heart's apex was displaced to right side. On 10th the tumour was double its original size.

Second Operation.—September 11. Exactly like the first in all particulars. Some difficulty experienced in introducing negative needle, which was somewhat rusty.

Result.—Tumour seemed tense; slight œdema of the skin. On 12th temperature 101° F. On 13th a drop or two of pus escaped from negative puncture. Temperature 103°. Tumour rapidly increased. On 15th skin covering it was red and tender, increase of œdema, pulsation very forcible. On 18th obscure crepitation felt in tumour. Red serous discharge oozed from negative puncture. On 20th a purple patch in centre of swelling. On 22nd patch had become gangrenous. Crepitation distinctly felt all over tumour. On 24th he died, with severe pain and symptoms of syncope.

Post-mortem.—Clot was found between layers of muscles covering the tumour. The muscles were sloughy, the clot was sponge-like, filled with gas, and had an offensive gangrenous odour. An enormous amount of extravasation of blood had taken place into the left pleura, and this had probably been the immediate cause of death. The sac contained a rupture (to which the pleura was adherent) big enough to admit the tip of the finger. The needles had not been introduced into the primary sac of the aneurism, but into a pleural extension of it. Two firm laminated masses of clot were found just inside the thorax, in the situation where the needles had been passed. They were dark purple in colour, and free from gas.

[The large 'secondary external' sac in this case, in which the author assisted Mr. Beck, was a most unfavourable circumstance. There can be no doubt that abundant electrolytic action took place at both operations. A considerable extension of the extravasation took place two days after the first operation, and it is possible that the formation of the electrolytic clots may have caused undue pressure on another weak part of the aneurismal wall, and so have brought about this extension. The sloughing of the integuments was probably due to the pressure, and was in no way connected with the punctures.]

Case XXXII.

Dr. M'Call Anderson's Case ('Lancet,' February 22, 1873). Mrs. H., age 46. Admitted to Glasgow Royal Infirmary November 8, 1871.

Probable Duration.—2½ years.

Seat.—Transverse and descending portion of the arch of the aorta.

Size and Character.—The tumour was conical, 3½ inches in diameter at its base. The apex projected 1½ inches from surface at the lower part of the left infra-clavicular region. It pulsated; a purring tremor could be felt in it. A well-marked systolic murmur was audible over the tumour. Left ventricle of heart dilated and hypertrophied. The tumour diminished somewhat in size by treatment—absolute repose, chloral, and the application of ice. Towards the end of March, 1872, it increased, and rupture seemed imminent.

First Operation.—April 4, 1872.

Positive Pole.—Insulated needle passed into sac.

Negative Pole.—A zinc plate, resting on a sponge applied to chest wall on the opposite side.

Current.—First four, then six cells of Stöhrer's battery.

Duration.—Half an hour.

Result.—Increased firmness of tumour and relief of symptoms.

Second Operation.—April 9. Exactly like the first.

Result (on April 26).—Tumour firmer and more solid; the symptoms much relieved. At the lower and middle part the tumour was softest and most expansile.

Third Operation.—April 26. Just like the others, the needle being passed into the soft part of the tumour.

On June 11 continued improvement in tumour was reported.

Fourth Operation.—August 27. Similar to the previous ones. Six cells were employed for fifteen minutes, eight cells for five minutes, and six cells again for ten minutes. When eight cells were used she complained of uneasiness and pain.

On October 26 it was noted that an apex systolic murmur had been superadded to the murmur audible over the tumour.

The tumour was, at the time of the report, only about one-quarter of its original size, and was, for the most part, very solid, much more so than the surrounding healthy parts of the chest. Purring tremor gone. Pulsation much less.

The history of this case is continued in the 'Lancet' for June 20, 1874. The facts are briefly as follows:—The patient disregarded all the directions which were given to her, as to leading a quiet life, &c., and eighteen months after her dismissal was re-admitted to the Royal Infirmary. Bronchitic râles were audible over the chest; symptoms of general passive congestion supervened; she became extremely livid, and died on January 7, 1874, 498 days after the last operation.

Post-mortem.—The inner surface of sternum was found much eroded, on a level with the second and third ribs. The upper part of the cavity of the thorax was occupied by a large tumour, measuring $4\frac{1}{2} \times 5\frac{1}{2} \times 6\frac{1}{2}$ inches. The bronchi were not much pressed upon. The right lung was slightly œdematous, and a few patches of condensation were noted. 'The left lung, which was partly adherent to the tumour, was completely carnified and flattened out, and compressed against the posterior wall of the chest.' The tumour was found to be an aneurism, formed by a 'dilatation of the aorta, implicating the whole of the transverse and descending portions of the arch, and projecting forwards. The great vessels sprang from the walls of the tumour. The aneurismal dilatation was completely filled with firm, pale, fibrinous, and stratified clots; but at the lowest part of the tumour the blood had partially separated the stratified clots from the walls of the aneurism, and penetrated the walls of the sac and the left pleura, on a level with the middle of the anterior edge of the compressed lung. The left pleura contained a considerable quantity of bloody serum and recent blood clots. The other organs of the body were healthy.'

Dr. Anderson thus records his opinion as to the best mode of operating :—' To sum up, then, although further experience on my own part, and upon that of others, may tend to modify my opinions on this subject, I am in favour of using a battery with large cells, of employing a weak current, of using one or more needles, insulated with vulcanite at that part which penetrates the skin and walls of the sac, and of connecting these needles in every case with the positive pole of the battery.'

[No mention is made in this case of the amount of corrosion of the needles. We should have thought eight cells hardly sufficient to cause electrolytic action in the face of such great resistance. The pain was probably caused by the big plates.]

Case XXXIII.

Mr. Holmes' Case of Innominate Aneurism. (' Lancet,' vol. ii., 1872).—A man, aged 50.

An aneurism of the innominate artery. Constitutional treatment had been tried with no success. The simultaneous ligature of subclavian and carotid was of little use in staying the disease. The rupture of sac being imminent, galvano-puncture was had recourse to. Four needles were inserted; they were used alternately as positive and negative pole, according to Cinicelli's method.

Current.—Ten to twenty-five cells of Foveaux's battery.

Duration.—Twenty-five minutes. A change of needles every five minutes.

Result.—Arterial blood jetted freely on withdrawal of needles. The tumour decreased in size for two days, then increased; diffuse inflammation occurred in and around the sac, and he died.

CASE XXXIV.

Mr. Holmes' Case of Traumatic Ulnar Aneurism.

Two needles were made to perforate the sac completely from side to side, and were connected with the *negative pole* of a battery, the current from which was continued for twenty minutes (no mention is made of the number or character of the cells employed, nor of the position of the positive pole). There was apparently no result. Bleeding followed the withdrawal of the needles.

CASE XXXV.

Mr. Holmes' Case of Aortic Aneurism.

'A large aortic aneurism, arising obviously very near the heart, and perforating the thoracic parietes on the right side, low down. The negative current was alone used "several times," but without any decided results, and again with the negative current and occasional intermissions of the positive. Then we applied both poles to the interior of the sac, a nodule of the tumour having approached so near to the skin as to threaten the speedy rupture of the aneurism. The effect was very striking, though I am sorry to say transitory. There was diminution in pulsation and increased firmness. The patient ultimately died from external hæmorrhage, occurring through one of the needle holes.'

CASE XXXVI.

Dr. Althaus records a case in which he used both poles in the sac of an aortic aneurism, in a man aged 48. There was no local reaction, and the patient appeared to improve locally and generally. He survived six weeks, and died of heart disease.

CASE XXXVII.

Dr. Ralfe's and Mr. Johnson Smith's Case ('Medical Times and Gazette,' January 17, 1874).—T. K., m., aged 41. Admitted to the Seamen's Hospital, July 11, 1873.

Probable Duration.—Sixteen months.

Seat.—First part of arch of aorta.

Size of Sac.—$2\frac{3}{4}$ inches × 2 inches.

Palliative measures and iodide of potassium were used for the first six weeks, at the end of which time the patient seemed to be worse.

First Operation.—August 28.

Positive Pole.—A large needle, insulated by a piece of gum-elastic catheter, inserted into the tumour at its most prominent part.

Negative Pole.—A plate of zinc and a layer of sponge placed upon the chest wall.

Current.—Five cells, gradually increased to fourteen and twenty of Foveaux's battery.

Duration.—Half an hour.

Result.—Partial reduction of pain and pulsation. The tumour was harder. The positive needle was black and roughened at its point. No sign of irritation round the puncture. Marked diminution of pain followed, and the patient was enabled to sleep better.

Second Operation.—September 5. Conducted as before.

Current.—Eight, increased to twenty cells of Foveaux.

Duration.—Forty minutes.

Result.—The skin under negative plate was 'very red.' Pulsation lessened. No pain.

Third Operation.—September 16. As before.

Duration.—One hour.

Result.—Nil.

Fourth Operation.—September 23. As before.

Current.—Twenty-three cells.

Duration.—One and a half hours.

Fifth Operation.—September 29.

Positive Pole.—Needle introduced into sac.

Negative Pole.—Needle introduced into sac.

Current.—Not mentioned.

Duration.—One hour.

Result.—Slight hæmorrhage from the punctures; much redness of skin over the tumour appeared on following day. 'This last operation, however, was followed in the course of three days by much relief of all the symptoms, and the tumour pulsated less, and became harder and less prominent.'

Sixth Operation.—October 7.

Positive Pole.—Needle in sac.

Negative Pole.—Ordinary rheophore held in the hand.

Current.—Ultimately thirty cells.

Duration.—One hour.

Result.—'Still more relief, both in the thoracic symptoms and local signs. The patient felt better and stronger, and, at his own request, was allowed to sit in a chair for two hours during the day.'

Seventh Operation.—October 14. Conducted in same manner as sixth.

Six days after, the skin over the most prominent part of the tumour was found to be red, and on the following day there was a small deposit of pus around the seat of the last puncture. The skin at this part also became soft and thin.

Eighth Operation.—October 22. Operation the same as last.

Duration.—One and a half hours.

Result.—The sitting seemed to reduce the pulsation, and the skin over centre of tumour became less red and tense.

October 27.—Skin red and œdematous; 'at the centre are four small pustules, the intervening skin being thin, and soft and baggy, as if infiltrated with pus.'

October 28.—Pulsation violent, and stream of blood very near surface.

Ninth Operation.—The same as the last three.

Duration.—An hour and a half.

Result.—Slight diminution of pulsation, and flattening of the summit of the tumour. The inflammatory symptoms then returned, and on the evening of November 4 there was a gush of blood from the orifices in the tumour (not the orifices, however, made by the last operation). This was repeated on the following morning, and he died.

Post-mortem.—The interior of the sac contained a mass of soft clots, some of which were readily washed away by a stream of water. The inner surface of the sac along the left concavity was quite exposed, but on the right concavity it was covered by a thick pyramidal mass of fibrin and firm clot, which occupied the whole of the right half of the sac. This mass, at and near its adherent base, was composed of a pale fibrinous mass in layers. Superimposed on this was an irregular mass of pink and softer deposit, and attached to the summit of the mass were several pendulous portions of soft clot, some of about the size of a pea, others as large as an almond. Most of these were firmly attached, and could not be detached by a stream of water.

The soft parts round the external opening were reddened and infiltrated with pus.

Case XXXVIII.

Dr. M'Call Anderson's Second Case of Aneurism ('Lancet,' June 13, 1874).—J. G., m., aged 34.

Probable Duration of Disease.—Three years.

Seat.—Upper surface of transverse portion of arch of aorta (none of large vessels directly involved in it) oval in shape, and five or six inches long.

First Operation.—October 22, 1873.

Positive Pole.—Needle in sac.

Negative Pole.—Zinc plate and sponge on chest wall.

Current.—Eight large cells of Stöhrer.

Duration.—Thirty minutes.

Result.—Nil.

Second Operation.—October 26.

Poles.—As at last operation.

Current.—First six, then eight cells of Stöhrer.

Duration.—One hour.

Result.—Burning pain in aneurism during operation. The tumour became firmer. A hard line observed along track of needle. Slight blush over tumour. Temperature, which had been 98·4°, rose to 99·3°.

The pressure symptoms slightly increased after this operation.

Third Operation.—November 2.

Poles.—As before.

Current.—Eight cells.

Duration.—Thirty minutes.

Result.—Intense burning pain during operation. No very decided result.

Fourth Operation.—November 7.

Positive Pole.—Needle in sac.

Negative Pole.—Needle in sac.

Current.—Six cells.

Duration.—Thirty minutes.

Result.—Intense burning pain during operation. An ounce of blood spurted from negative aperture on withdrawal of needle. Tumour became less firm and more prominent.

Fifth Operation.—November 23.

Poles.—As at first three operations.

Current.—Six cells.

Duration.—Thirty minutes.

Result.—Burning pain. Tumour became more prominent and pointed.

Sixth Operation.—December 1. Six cells for fifty minutes.

On December 10 oozing of bloody serum occurred from most prominent part of tumour.

Seventh Operation.—December 14.

Positive Pole.—Three needles (not insulated) inserted into sac.

Negative Pole.—?

Current.—Six cells.

Duration.—One hour.

On December 18 patient died from bursting of the sac.

Post-mortem.—The sac was almost completely filled with old and recent clots, and at one place, almost in the middle of the sac, and in a line with one of the needle punctures, there was a very distinct stratified coagulum, which was much paler and firmer than the rest.

[No mention is made of the amount of corrosion of the needles. The needles were not insulated, and to this, in a private communication kindly made to the author, Dr. M'Call Anderson attributes the burning. The author, however, feels that the large plates were also, in part, answerable.

CASE XXXIX.

Mr. A. F. M'Gill's Case of Subclavian Aneurism (treated at the Leeds Infirmary) ('Lancet,' vol. ii., 1874, p. 9).—A woman, aged 35, a laundress.

Probable Duration.—One year and four months. (Probably caused by a blow.)

Seat.—'Third part of the left subclavian.'

Size of Sac.—The tumour projected above and as far as three inches below the clavicle, where it could be felt pulsating.

First Operation.—April 23.

Positive Pole.—Insulated steel needle introduced into sac.

Negative Pole.—Insulated steel needle introduced into sac.

Current.—Five cells of Weiss's (Foveaux's) battery.

Duration.—Three-quarters of an hour.

Result.—Nil. Twitching of the muscles was observed when the current was first passed, and great pain was occasioned, which was increased when the points of the needles came accidentally in contact within the sac.

Second Operation.—May 3.

Positive Pole.—Platinum needle inserted into sac.

Negative Pole.—Steel needle inserted into sac.

Current.—At first ten, then fifteen cells of Weiss's battery.

Duration.—Two hours and a half.

Result.—'In a few minutes the skin of the hand became red and mottled, presenting the appearance of urticaria; this gradually spread up the arm, and was accompanied by intense itching followed by a burning pain, which in half-an-hour became so intense that it was necessary to administer chloroform. The aneurism gradually solidified; it increased in size, but did not become tympanitic; after an hour and a half no pulsation could be detected.' On withdrawing the needles 'there was slight oozing of arterial blood, which was soon stopped by the application of collodion and cotton wool. . . . For thirty hours no pulsation could be felt, but at the end of that time a slight beating could be detected. This gradually increased till, at the end of a week, it was almost as severe as before the operation. The pain was, however, much relieved, and she slept well.'

Third Operation.—May 23.

Positive Pole.—A damp sponge applied over the aneurism.
Negative Pole.—Three needles introduced into the sac.
Current.—Twenty cells of Weiss's battery.
Duration.—Three-quarters of an hour.
Result.—Nil.

For two months there was no return of the pain, and the aneurism gradually got harder. On July 18 there was a severe thunderstorm. The patient was much frightened, being up the greater part of the night. The next day the pain returned and the pulsation was increased.

Fourth Operation.—July 23. The same plan was followed as at the second operation on May 3. The duration was 2¾ hours, and chloroform was administered.

Result.—The symptoms both during and following the application of the galvanism were the same as on the previous occasion. 'She has since been almost free from pain, and the aneurism has been getting gradually harder and more solid. She has now (November 1, 1873) been working for a fortnight as a mill cook, and, notwithstanding the hard work, there is only the slightest pulsation.'

Remarks (by Mr. M'Gill).—'1. It is advantageous to give the patient chloroform before commencing the operation, as, without it, it is impossible to prolong the operation for a sufficient time. 2. The needles should be well insulated to avoid burning the skin around that connected with the negative pole. 3. The current should be passed for at least two hours; very probably twice that time would be advantageous. 4. The operation by the insertion of the needles connected with the negative pole had, in my hands, no effect whatever. 5. The patient should be kept quiet in bed after the galvano-puncture.'

[This aneurism recurred, and was subsequently subjected to operation.]

CASE XL.

Dr. Brandis' (of Aix) Case of Femoral Aneurism cured by combined Instrumental Compression and Galvano-Puncture.—L. W., a male, aged 33.

Probable Duration.—Five or six years.

Seat.—Just below Poupart's ligament.

Size.—Two fists.

First Operation.—October 17, 1874. Chloroform was administered, and the external iliac artery was compressed.

Positive Pole. *Negative Pole.*	Platinum needles insulated with lac. The needles were first connected with positive pole (six minutes) and then with negative. They were then introduced in another place, and the process repeated.

Duration.—Thirty-four minutes.

Current.—Thirty cells of Stöhrer.

Result.—The lac melted round the needles, and eschars were produced. Much gas was liberated in the tumour, which became tympanitic and the surrounding skin emphysematous. The compression was continued for two hours and three-quarters. Four hours after operation the pulsation had ceased and the size had diminished. The pulsation never returned, the needle tracks suppurated, and an abscess formed beneath the fascia on the outer side of the thigh. In four months the tumour had gone and the patient was apparently quite cured.

CASE XLI.

Dr. Henry J. Bowditch's Case of Galvano-Puncture ('London Medical Record,' March 5, 1873).

Patient.—An adult male.

Seat.—Aorta; tumour projected in second right intercostal space.

First Operation.—November 12, 1872.

Positive Pole.—Three needles coated with vulcanite.

Negative Pole.—'Resting on right breast on a level with the tumour.'

Current.—Two to sixteen cells of Stone's battery.

Duration.—14¼ minutes.

Result.—Some faintness and pulselessness. Solidification of the tumour and swelling of the parts adjacent. No superficial redness or sloughing of the skin occurred. No air appeared in the tumour.

Second Operation.—November 17, 1872. Like the first in all particulars, except that twenty-eight cells were employed.

Result.—Similar to the result of the first. The patient suffered not at all from the proceeding, and was more comfortable than before the first operation.

CASE XLII.

Dr. Green's Case of Aortic Aneurism.—J. C., aged 37, admitted to Charing Cross Hospital, February 27, 1875.

Seat and Character.—Sacculated aneurism (?) occupying the ascending portion of the arch of the aorta. On admission there was no projecting tumour, but impulse was visible in second and third right intercostal spaces. Lancinating pains were very troublesome.

Probable Duration.—Possibly three years, certainly six months. Various treatment was pursued till March 17, when galvano-puncture was resolved upon.

First Operation.—March 17.

Positive Pole. } Steel needles insulated with gum-elastic
Negative Pole. } (size of ½ catheter), both introduced into sac.

Current.—Thirty-two cells of Foveaux's battery, only about one-third of the area of the plates being immersed. [The author assisted Dr. Green at this operation, and employed a battery to which an immersion regulator had been fixed. See Fig. 11.]

Duration.—Seventy minutes.

Result.—No extra pain was complained of during the operation, for no anæsthetic, either general or local, was employed. The needles were inserted and withdrawn without difficulty. No hæmorrhage. *The point of the positive needle was completely dissolved away.* The needle punctures gave rise to no trouble whatever. The effect upon the objective and subjective symptoms of the patient was absolutely nil.

The patient refused to submit to a second operation, and left the hospital on June 8, 1875, there being at that time a slightly projecting tumour. He could walk about without much difficulty, and his general condition was slightly improved.

[This operation was in one sense very successful, for a powerful electrolytic action was undoubtedly set up in the sac, and from that action one cannot but suppose that a clot resulted. The non-projection of the aneurism was a circumstance unfavourable for the detection of diminution of size or increased consolidation (supposing such to have at any time occurred).]

CHAPTER X.

ELECTRICITY AS A CAUTERY.

We have seen that the physician when employing electricity makes use mainly of its specific stimulating and sedative effects upon nerves and muscles. The surgeon also not unfrequently has recourse to electricity for similar objects, but more frequently he employs those thermal and chemical effects which the galvanic current is capable of producing. The galvanic cautery consists of a platinum wire heated to redness by a galvanic current. When discussing Ohm's law it was pointed out that when the external resistance was small the intensity of the current was increased, not by increasing the number of the elements, but by increasing their superficial area. In the arrangement for the galvanic cautery the external resistance is very small—the circuit being closed completely by a metallic arc—and therefore, since the heating power of the current is in direct proportion to its intensity, we use a battery composed of elements of large superficial area and of high electromotor force. The elements are placed as near as possible to each other without actually touching, and the liquids employed have a high conducting power, and in this way the internal resistance is reduced to a minimum. The arrangement which is capable of producing the greatest amount of heat is known as Hare's Deflagrator. It is so constructed as to facilitate as much as possible the conduction of the electricity between the zinc and copper plates. It is formed of two very large plates of zinc and copper rolled in a spiral manner parallel to each other upon a central cylinder of wood. The two plates are prevented from touching each other by pieces of cloth or twine inserted between them. The plates thus arranged are plunged into a vessel of acidulated water, and the metallic arc which connects them becomes speedily heated.

The usual form of battery for the galvanic cautery is composed of half-a-dozen Grove's or Bunsen's elements.

The metallic circuit is formed for the greater part of its extent by a copper wire of enormous calibre, often as much as a quarter of an inch in diameter. This conductor of low specific resistance and large sectional area offers, practically speaking, no resistance to the current, and notwithstanding the enormous quantity of electricity which flows through it, its temperature is not perceptibly raised. The large copper wires are united by a fine platinum wire, which, on account of its small sectional area and high specific resistance, offers great obstruction to the current, and consequently becomes speedily heated. *Cœteris paribus*, the smaller the wire the more readily it is made redhot. If the platinum wire be too small in proportion to the intensity of the current, it will melt. The size of this wire may be altered according to circumstances. If the work to be done is trivial, as, for example, the cauterisation of a small nævus, a fine wire and a current of small intensity may be used. If, on the other hand, the cauterisation of deep-lying tissues of considerable extent is to be effected, the platinum wire must be thicker and the intensity of the current must be increased. The platinum wire is, for convenience, mounted upon a rheophore to which the large copper conductors are attached (Fig. 28, 1). This rheophore has an insulated handle (A), and by a simple contrivance the circuit can be opened or shut by the thumb of the hand which holds the instrument (K).

The great advantage of the galvanic cautery is the fact that it is completely under control. It may be applied cold to any part of the body, and need not be heated until after it is satisfactorily *in situ*. This is an advantage upon which it is needless for us to dwell. Another great advantage lies in the fact that its heat can be constantly maintained, and the necessity of having relays of cauteries is thereby abolished. Again, the size of the cautery may be varied, within certain limits, at will. If we wish for a small cautery, we may have one the size of a pin's head by making a loop of fine platinum wire, as has been stated. If we wish for a bigger cautery, we may employ a coarser wire, or we may make our wire encircle a mass of porcelain (Fig. 28, 5, 6, 8), which, by the heating action of the wire, soon becomes redhot, and we are thus provided with a cautery large enough, and certainly powerful enough, for any purposes that may be required.

A very convenient modification of the galvanic cautery is the 'galvanic écraseur' (Fig. 28, 1). In this instrument the heated platinum loop can be gradually tightened by a screw action, so that any tissues included by the loop will be speedily divided.

After the Grove's or Bunsen's batteries which supply the current for the cautery have been used, the plates must be immediately removed from the liquid, be thoroughly washed, and then exposed to the air till they are quite dry.

These batteries of high electromotor force are troublesome to keep in order; they are easily damaged, and, unless great care be exercised in the management of them, they are liable to disappoint the surgeon when the cautery is wanted. They further have the disadvantage of giving off nitrous fumes which often prove annoying to the surgeon and the patient. Messrs. Mayer & Meltzer have constructed a galvanic cautery which is free from these objections (Fig. 27). They have taken advantage of the fact which we pointed out while discussing Ohm's law, that the size of the plates may be practically increased by uniting all the generating plates in a battery together, and all the collecting plates. In this way we attain the same end as is got by increasing the area of the individual plates, and the result is an instrument which is far less cumbersome and more portable than the batteries in ordinary use. The battery we have seen consists of twenty-seven pairs of zinc and carbon plates, each plate having a superficial area of 3 inches by

$1\frac{1}{2}$ inches. All the zincs and all the carbons are united to each other, and the exciting fluid—a solution of bichromate of potash to which sulphuric acid has been added—is one which gives no fumes. With this battery all the effects are obtained which can be got by the Grove's or Bunsen's batteries which are ordinarily used. It is necessary to keep the exciting fluid constantly in motion, and this has been accomplished by a simple contrivance by means of which the elements can be made to rock to and fro in the cells.

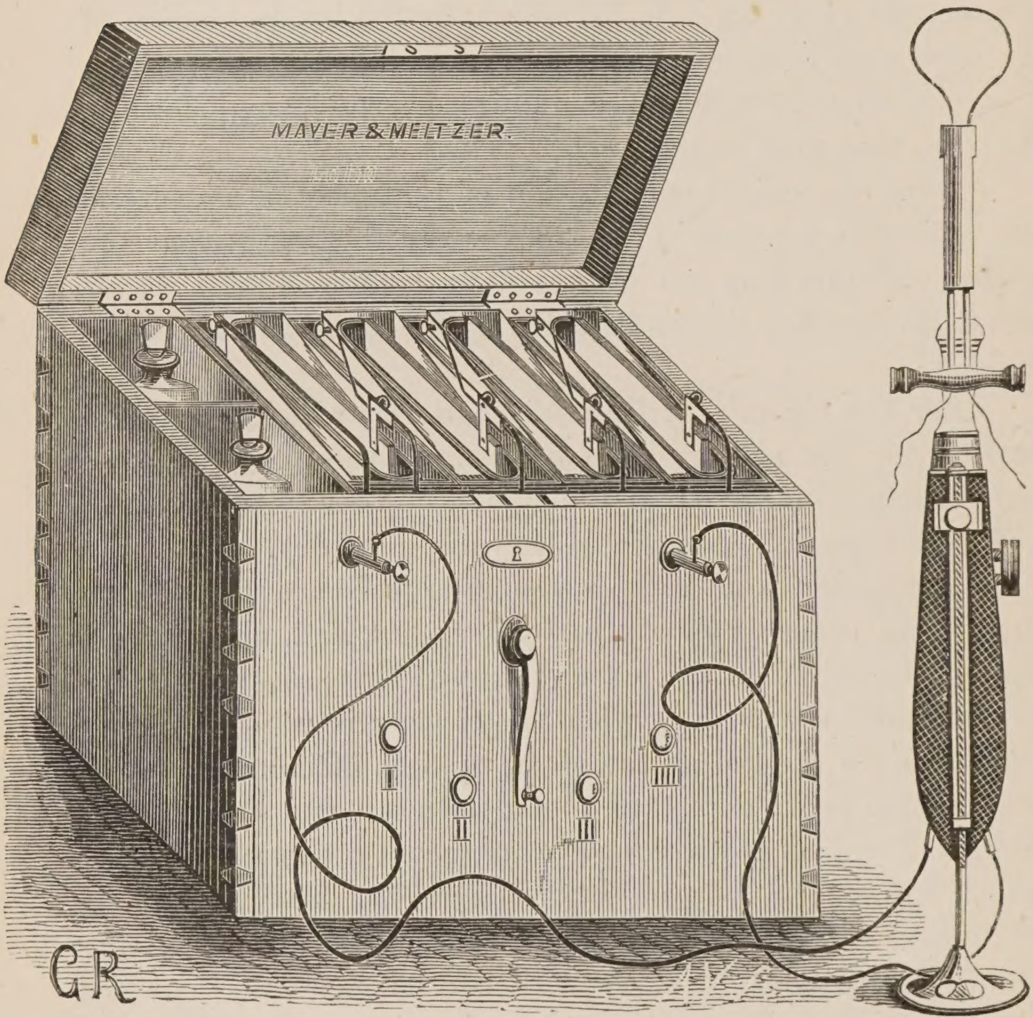


FIG. 26.—Large-celled Bunsen's battery for the galvanic cautery.

It is not for us to point out those cases in which the galvanic cautery would seem to be most useful. We have shown what are the peculiar advantages which the cautery possesses, and it is for the surgeon to determine in what cases these advantages are likely to be of service to him. We may merely say that it has been employed with success for the destruction of the dental pulp, for the destruction of nævi, and for the arrest of hæmorrhage in situations which an ordinary cautery would be unable to reach. Growths have been removed from the larynx by means of the galvanic écraseur, and pedunculated polypi in various situations have been destroyed by its agency. Professor John Marshall has used this cautery with great success for the treatment of fistulæ; and for all operations where hæmorrhage is the dangerous element, such as the removal of the tongue and the amputation of the penis, the écraseur has proved itself invaluable.

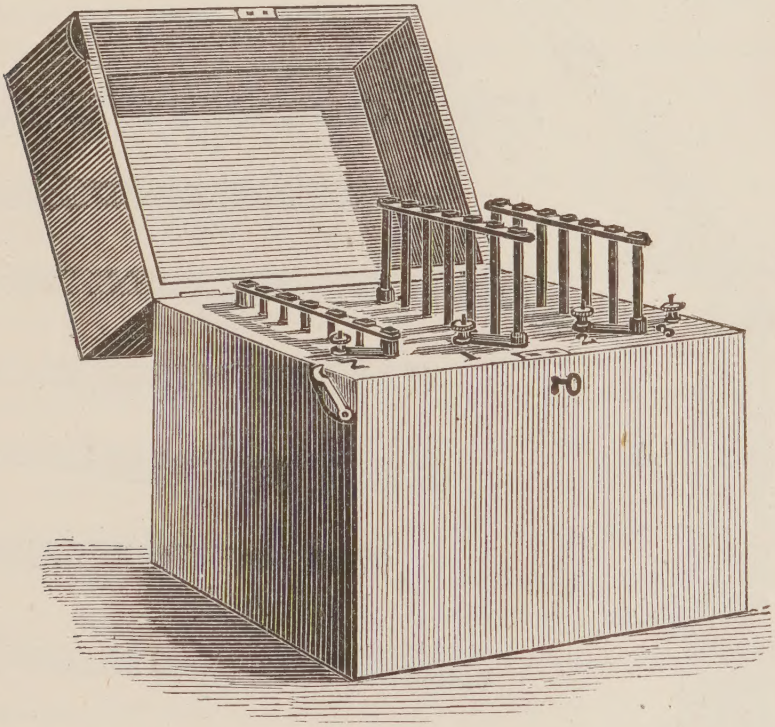


FIG. 27.—Mayer & Meltzer's battery, with small plates, for the galvanic cautery.

The figure on next page represents the set of instruments usually supplied with the galvano-cautery battery.

Fig. A shows the instrument, or holder, which carries all the various instruments from No. 1 to 9, comprising double canulæ of various sizes and lengths for carrying a platinum wire loop, as well as those for cauterising cavities and surfaces.

An instrument made of platinum, and having the form of a knife, has also been manufactured, and has been employed for dividing tissues in cases where hæmorrhage has to be avoided.

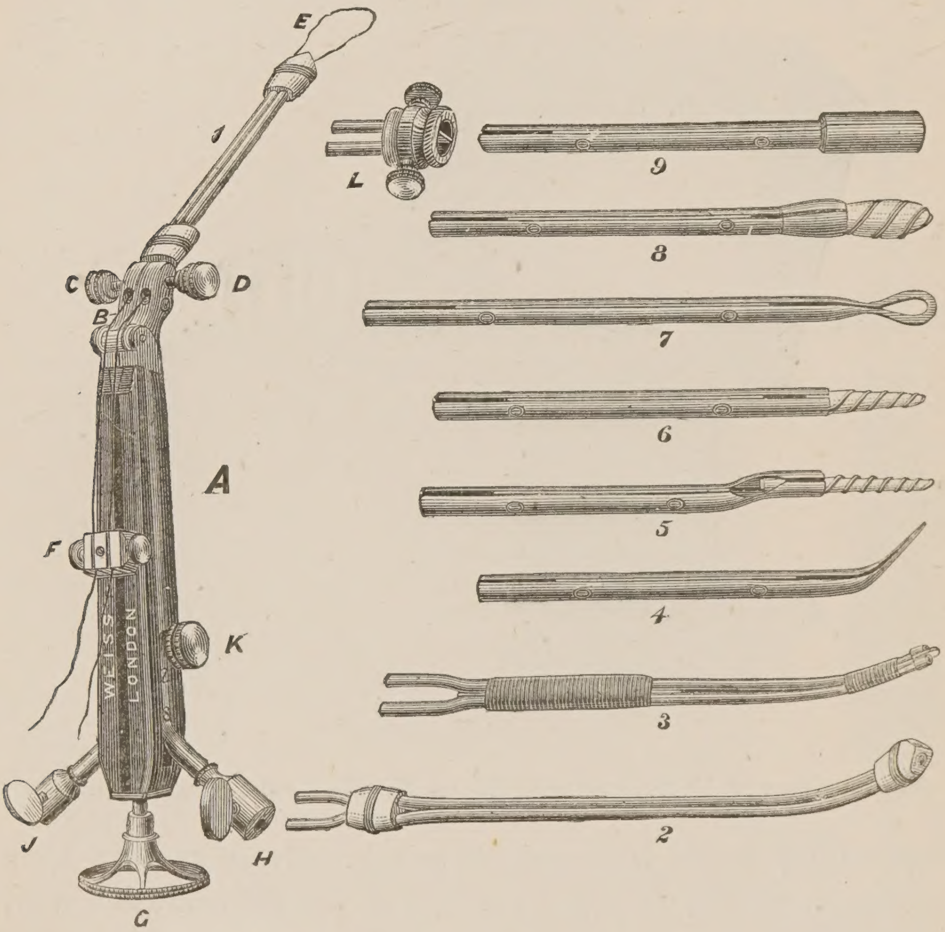


FIG. 28.—Galvanic écraseur and various forms of cautery.

In the 'Lancet' (vol. i., 1874) will be found some interesting and instructive lectures by Mr. Bryant, of Guy's Hospital, on the employment of the galvanic cautery in surgery. The method of operating with the galvanic cautery is, according to Mr. Bryant, the only truly bloodless method which we possess. To Professor John Marshall, of University College Hospital, belongs the credit of having first used the galvanic cautery for surgical purposes; but it is to Dr. Middeldorp, of Breslau, we owe the perfection of detail in battery and apparatus which has rendered this method so generally applicable.

Operations on the Tongue with the Galvanic Cautery.—Mr. Bryant says: 'There are no operations of importance that the surgeon has to perform which have been more benefited and simplified by the introduction of the galvanic cautery than those upon the tongue, for there are none in which, without its use, hæmorrhage is more troublesome or dangerous, and there are none, with its use, which more satisfactorily illustrate its bloodless character. Indeed, before the introduction of the galvanic cautery or écraseur, operations on the tongue were very rarely performed.' The following are Mr. Bryant's directions for removing portions of the tongue by means of the galvanic écrasure:—'For the removal of a cancerous nodule of the tongue, or of a cancerous tongue, wholly or in part, the first thing a surgeon has to do is to isolate the part to be removed, and this can usually be effected by the introduction of long pins, ivory pegs, or curved needles in handles beneath the base of the growth . . . and in doing this the surgeon had better go wide of the disease. Having isolated the growth by this means, fixed the mouth open by a gag, and had the tongue drawn forwards as far as possible, either by means of tongue forceps or, what is far better, a whipcord ligature passed through the tip of the organ, the loop of the galvanic écraseur is to be passed round the base of the disease behind the pins and gradually tightened, the connection between the poles of the battery being made as soon as the wire loop has been adjusted, but not before. The process of tightening and cauterising may then be carried out; and when performed successfully the part to be removed will quickly fall off without the loss of a drop of blood. In this process of tightening and cauterising much care is called for. In the first place, the wire that is employed should be thick or twisted. I believe the twisted platinum wire is better than the thick. This wire should not be heated beyond a red heat, and the redness ought to be of a dull kind. But above all, the process of tightening should be very slowly performed, the wire of the écraseur being screwed home only as it becomes loose by cutting through the tissues; any force may break it, and thus give rise to difficulties, or cut through the tissues too rapidly, and thus give rise to bleeding. Whenever bleeding follows the operation that has been described, it is from one of two things—the wire cautery has been used at too great a temperature, or has been screwed up too rapidly. The surgeon had better take a few minutes longer at his operation than fail in obtaining good effects.'

As the loop shortens it is very important to decrease the intensity of the current by including fewer cells; for as the loop gets shorter, *cæteris paribus*, it becomes hotter, and it not unfrequently happens that the last and often the most vascular portions are divided with undue and very dangerous rapidity.

Amputation of Penis with Galvanic Écraseur.—Mr. Bryant ('Lancet,' 1874) says: 'This operation . . . in no way endangers life. When performed with the galvanic écraseur the operation is simple and bloodless. . . . The surgeon in performing it is only called upon to be careful to apply the wire well above the disease, and to be slow in the screwing up of the écraseur, having previously satisfied himself that the battery is in working order, and that the wire employed is of a dull red heat. On the completion of the operation a catheter should be passed and left in; and as the wound heals a short bougie should be introduced into the orifice of the urethra to prevent its subsequent contraction. With attention to these points there is rarely any subsequent source of trouble to be looked for. In all the cases of amputation of the penis (for cancer) that I have performed or seen performed, much comfort has followed the operation, and with the galvanic écraseur the operation is so satisfactory that I recommend the removal of the organ when extensively diseased, even when enlargement of the inguinal glands exists, on account of the comfort the operation affords.'

For the treatment of lupus, epithelial cancer, and some forms of nævi, the galvanic cautery, says Mr. Bryant, 'possesses advantages such as are not equalled by any other means the surgeon has at his command. It is applied with facility, certainty, and success, and it has rendered the treatment of these hitherto troublesome affections comparatively a simple matter; for in many of the cases . . . one application of the galvano-caustic was sufficient to set up a new action in the part, and heal a lupus, destroy a cancer, or cure a nævus.'

Treatment of Nævi by the Galvanic Cautery.—Mr. Bryant points out that there are three varieties of nævus: '(1) the purely skin nævus, that involves the skin alone, and appears as a more or less extensive and bright vascular mark; (2) the purely subcutaneous nævus, that involves the cellular tissue placed beneath the skin, and that does not affect the integument over it; and (3) the mixed form of nævus, which affects both the tissues, beginning either in the skin and spreading deeply, or in the cellular tissue and growing forwards. Of these three varieties, the first and the last are the more amenable to the treatment by the galvanic cautery; the first with a good certainty of securing a successful issue, and the last with a fair certainty. The purely subcutaneous may be so dealt with, but as a general rule these cases are better treated by excision or by subcutaneous ligature.'

In the treatment of the purely skin nævus, the surgeon must take care that the whole thickness of the vascular tissue is destroyed. He must burn it down by means of the platinum point, spatula, or porcelain cautery till the whole is destroyed and carbonised. He must see that the margins of the growth are freely cauterised as well as the centre; the base of the disease as well as the surface. He must not show any timidity in the use of the burning instrument; he must use it boldly, to the complete destruction of the vascular tumour. He must so cauterise the whole nævus as to turn it into a brown, non-vascular, solid eschar. In the treatment of the mixed variety of nævus the same care is called for, and the same boldness of execution; but something additional is required, and that is the perforation of the subcutaneous portion of the nævus by the heated wire. The whole mass should be riddled in all directions; the platinum wire should be introduced into it vertically, transversely, or obliquely; every part of its structure should be brought under the influence of the cautery; and under such circumstances, the withering of the whole may with some confidence be looked for.'

Treatment of Hæmorrhoids and Prolapsus Recti with the Galvanic Cautery.—Mr. Bryant says: 'The operation for the removal of hæmorrhoids, or the cure of prolapsus recti, with the galvanic cautery, differs in no respect from that usually performed with the common cautery. The bowel to be treated is brought well down and into view by means of the patient who is made to strain over a pan of hot water, or by an enema of warm water. The different portions of the bowel to be removed are then seized, and clamped in vertical pieces radiating from the anus, each clamped portion, or rather the upper half of each portion, being then cut off with scissors. The parts are then ready for the application of the cautery—the porcelain cautery heated to a red heat. This is to be rubbed over the surface of the projecting mass till it is burned down to the level of the clamp, and turned into a dry eschar; each piece is to be dealt with in order, and each clamp removed as its segment is cauterised, the whole being carefully returned and pressed into the rectum when the operation has been completed. When the cautery is efficiently applied, no bleeding follows the operation and very little pain. The pain induced after the galvanic cautery is far less than that which follows the actual cautery.'

Treatment of Fistula in Ano by the Galvanic Cautery.—Mr. Bryant says: 'The treatment of fistula *in ano* by the galvanic cautery is as simple as it is satisfactory. It is performed as follows:—The platinum wire, or twist of platinum wire, is first introduced into the fistula, and I generally do this through the groove of the probed director, when it has been made to pass through the fistula into the bowel. I then hook with the finger, that is in the rectum, the end of the wire downwards through the anus, and remove the grooved probe, in this way one end of the wire being made to protrude through the rectal orifice of the fistula out at the anus, and the other through the external orifice of the fistula. The two ends of the wire are then connected with the poles of the charged battery and the wire heated, the division of the fistula being made by means of the écraseur, or a gentle sawing movement of the wire, or traction upon it. The wound may then be dressed with oiled lint or cotton wool, and the case treated upon ordinary principles, the wound having simply to heal by granulation.'

Case XLIII.

Tubal Pregnancy. Operation with the Galvanic Knife.—Dr. J. G. Thomas communicated to the 'New York Medical Journal' for June 1875 the following case:—

A married lady, æt. 37, menstruated last on October 25, 1874. In January 1875 she began to experience cramp-like pain and uneasiness in the left iliac fossa. On vaginal examination by Dr. Thomas, on February 4, the uterus was found to be larger and less mobile than normal; a tense elastic cyst, which filled the whole iliac fossa, dipped into the pelvis and pushed the uterus over to the right side. *Ballottement* was detected.

On February 7, the patient having been etherised, was placed on a table before a window admitting a strong light, in the left lateral position, and Sims' speculum was introduced. The uterus was then steadied by a tenaculum in the cervix; and with the platinum knife of the galvano-caustic battery, which was brought to a white heat, the vaginal roof was slowly cut through. 'In six minutes the cyst was opened by the incandescent knife, and a straw-coloured slightly pinkish fluid was thrown out with such force as to fly into my face and over my clothing.' No blood whatever was lost thus far. The index finger was then passed into the cyst, and a fœtus detected lying horizontally. Extraction by the feet, aided by a pair of long-handled placental forceps to deliver the head, was resorted to, and the cord was then cut. Gentle traction and detachment of the placenta was then attempted; but when a little over half had been separated, a very severe hæmorrhage took place. This was checked by the injection of a solution of persulphate of iron. A long tent of carbolised cotton saturated with a solution of persulphate of iron was then inserted, and the patient removed to bed. On the fourth day symptoms of septicæmia showed themselves. On the seventh there was some hæmorrhage. On the fifteenth the remaining part of the placenta came away. Within ten weeks the patient became perfectly convalescent. ('London Med. Record,' July 15, 1875.)

Spermatic Cord.—Dr. Beeckel has used the galvanic cautery to divide the spermatic cord.

Tracheotomy with the Galvanic Cautery.—M. Bourdon records eight cases. Amussat transfixed the trachea with a platinum wire, which, being subsequently heated by the battery, served to divide it and its integuments. M. Verneuil prefers operating with a knife heated by a galvanic battery. The advantage claimed for 'galvanic tracheotomy' is the avoidance of hæmorrhage.

Amputation of Limbs by the Galvanic Cautery.—Dr. Paul Bruns records twelve amputations of limbs by the galvanic cautery: eight amputations of the thigh, two of the leg, one of the forearm, and one of the finger. There seems to be no advantage in such a proceeding, which certainly savours of mediævalism and retrogression.

Sero-Sanguineous Cyst of the Neck.—Dr. Amussat, jun., has successfully treated a large cyst by passing a platinum wire through it, heating the wire to redness by means of a battery, and thus burning the interior of the cyst. (‘London Medical Record,’ January 28, 1874.)

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